STUDIES ON THE BARK ANATOMY OF SOME CULTIVATED TREES

ABSTRACT

Ph. D. Thesis

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ABSTRACT

The present study on the bark anatomy of some cultivated leguminous trees of Aligarh (Uttar Pradesh) and Bhopal (Madhya Pradesh) has yielded the following information:

1. The barks on the basis of surface characteristics are categorized as:

   (i) Smooth or non-fissured: Acacia farnesiana, Cassia javanica, C. nodosa, Delonix regia, Erythrina indica, Gliricidia maculata, and Saraca indica.

   (ii) Shallow-fissured: Cassia siamea, Hardwickia binata, Parkia roxburghii, Sesbania grandiflora; and Tamarindus indica.

   (iii) Deep-fissured: Cassia fistula, C. renigera, Erythrina suberosa, Peltophorum pterocarpum, Prosopis juliflora, Pterocarpus marsupium and Samanea saman.

2. The bark peels off in the form of scales of various shapes and sizes in different investigated species except Erythrina indica, in which the bark sheds off in the form of thin papery flakes. The average surface area of shedded bark scales varies from 1.7 x 1 mm^2 to 125 x 43 mm^2 in different species studied viz. 1.7 x 1 mm^2 in Saraca indica 2.8 x 1.5 mm^2 in Acacia farnesiana, 3.8 x 2.7 mm^2 in Gliricidia maculata, 6.6 x 2.2 mm^2 in

Sesbania grandiflora, 7.3 x 4.4 mm^2 in Cassia nodosa, 10.8 x 10.2 mm^2 in Hardwickia binata, 11.8 x 5.7 mm^2 in Delonix regia, 12.3 x 8.4 mm^2 in Parkia roxburghii, 30.3 x 17.1 mm^2 in Cassia siamea, 43.1 x 21.5 mm^2 in C. renigera, 48.2 x 26 mm^2 in C. fistual, 50.3 x 23.3 mm^2 in Pterocarpus marsupium, 63 x 36 mm^2 in Erythrina suberosa, 64 x 32 mm^2 in Peltophorum pterocarpum, 68.5 x 30.7 mm^2 in Tamarindus indica, 92 x 11 mm^2 in Prosopis juliflora, and 125 x 43 mm^2 in Samanea saman.

3. The ray expansion tissue is prominent and visible in slash with the naked eye in Acacia farnesiana, Cassia fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Delonix regia, Erythrina indica, E. suberosa, Gliricidia maculata, Hardwickia binata, Parkia roxburghii, Peltophorum pterocarpum, Pterocarpus marsupium, Saraca indica and Sesbania grandiflora, whereas it is not visible in Prosopis juliflora, Samanea saman and Tamarindus indica.

4. Micromorphologically, the barks easily be recongised into outer and inner zones, the former consisting of rhytidome and latter of secondary phloem, the depth of which differed in different species. The secondary phloem has two distinct parts i.e., the conducting and the non-conducting ones in all the species.

5. The depth of rhytidome varies from 0.2 mm to 18.2 mm in different species viz. 0.2 mm in Erythrina indica, 0.5 mm in Cassia javanica, 0.5 mm in C. nodosa, 0.5 mm in Saraca indica, 0.7 mm in Cassia siamea, 1 mm in Acacia farnesiana, 1 mm in Delonix regia, 1.4 mm in Gliricidia maculata, 2.2 mm Sesbania grandiflora, 2.3mm in Parkia roxburghii, 2.3 mm in Peltophorum pterocarpum, 3.4 mm in Hardwickia binata, 4 mm in Prosopis juliflora, 4 mm in Tamarindus indica, 6.8 mm in Cassia fistula, 6.8 mm in Pterocarpus marsupium, 8.9 mm in Samanea saman, 16.3 mm in Erythrina suberosa,and 18.2 mm in Cassia renigera.

6. The depth of the conducting phloem ranges from 0.4 mm to 2.5 mm among the investigated species viz. 0.4 mm in Cassia siamea, 0.5 mm in Erythrina indica, 0.6 mm in Accacia farnesiana, 0.6 mm in Delonix regia, 0.7mm in Cassia fistula, 0.7 mm in C. javanica, 0.7 mm in Prosopis juliflora, 0.7 mm in Pterocarpus marsupium, 0.7 mm in Sesbania grandiflora, 0.8 mm in Hardwichia binata, 0.8 mm Saraca indica, 1 mm in Cassia renigera, 1 mm in Peltophorum pterocarpum, 1.2 mm in Erythrina suberosa, 1.5 mm in Samanea saman, 1.5 mm in Tamarindus indica, 1.7 mm in Gliricidia maculata and 2.5 mm in Cassia nodosa.

7. The depth of secondary phloem varies from 2 mm to 14 mm: 2 mm in Acacia farnesiana, 3.4 mm in Delonix regia, 4 mm in Saraca indica, 4.5 mm in Sesbania grandiflora, 5.2 mm in Prosopis juliflora, 5.3 mm in Cassia siamea, 5.6 mm in Gliricidia maculata, 5.8 mm in Cassia renigera, 6 mm in Peltophorum pterocarpum, 6.2 mm in Pterocarpus marsupium, 6.3 mm in Erythrina suberosa, 6.5 mm in Tamarindus indica, 7.2 mm in Cassia javanica, 7.7 mm in Samanea saman, 8.6 mm in Hardwickia binata, 10.3 mm in Erythrina indica, 10.6 mm in Parkia roxburghii, 11.7 mm in Cassia fistula, and 14 mm in Cassia nodosa.

8. The phloem fibres are non-septate in thirteen species except six species: Casia renigera, Hardwickia binata, Peltophorum pterocarpum, Prosopis juliflora, Sesbania grandiflora and Samanea saman have septate fibres.

9. The fibres occur in the form of continuous regular tangential bands in Acacia farnesiana, Parkia roxburghii, Prosopis juliflora, Samanea saman and Sesbania grandiflora, as fascicles of varying size arranged more or less in discontinuous tangential bands in Cassia nodosa, C. siamea, Erythrina suberosa, Gliricidia maculata, Hardwickia binata, Peltophorum pterocarpum, and Pterocarpus marsupium and as irregularly distributed isolated elements or groups of different size in Cassia fistula, C. javanica,

C. nodosa, C. renigera, Delonix regia, Erythrina indica, Saraca indica and Tamarindus indica.

10. The total average amount of fibres in the secondary phloem constitute about 5.96% in Erythrina indica, 7.06% in Delonix regia, 8.45% in Erythrina suberosa, 10.04% in Parkia roxburghii, 10.09% in Gliricidia maculata, 10.34% in Hardwickia binata, 10.94% in Pterocarpus marsupium, 11.69% in Cassia javanica, 12.30% in Prosopis juliflora, 12.56% in Cassia renigera, 13.26% in Tamarindus indica, 13.35% in Cassia siamea, 13.59% in C. fistula 13.65% in Samanea saman, 14.23% in Peltophorum pterocarpum, 16.27% in Saraca indica, 17.48% in Sesbania grandiflora, 18.39% in Acacia farnesiana and 22.47% in Cassia nodosa.

11. The mean length of fibres varies from 592.80 µm to 1742.08 µm in various investigated species viz. 592.80 µm in Cassia renigera, 637.76 µm in C. nodosa, 650.88 µm in C. javanica, 770.56 µm in Gliricidia maculata, 839.52 µm in Cassia fistula, 851.20 µm in Peltophorum pterocarpum, 900.96 µm in Tamarindus indica 976.64 µm in Prosopis juliflora, 995.36 µm in Cassia siamea, 1055.68 µm in Samanea saman, 1083.36 µm in Saraca indica, 1111.20 µm Parkia roxburghii, 1198.56 µm in Acacia farnesiana, 1201.76 µm in Sesbania grandiflora, 1236.81 µm in Pterocarpus marsupium 1281.28 µm in Erythrina suberosa,1548.64µm

in Hardwickia binata 1599.36 µm in Erythrina indica and 1742.08 µm in Delonix regia whereas the width varies from 12.22 µm to 31.20 µm viz. 12.22 µm in Hardwickia binata, 14.56 µm in Parkia roxburghii, 16.16 µm in Tamarindus indica 16.32 µm in Peltophorum pterocarpum, 17.92 µm in Samanea saman, 18.08 µm in Delonix regia, 18.24 µm in Erythrina indica, 19.60 µm in Cassia siamea, 19.84 µm in C. renigera, 19.68 µm in C. fistula, 20 µm in C. javanica, 20 µm in Sesbania grandiflora, 20.63 µm in Prosopis juliflora, 20.77 µm in Acacia farnesiana 22.08 µm in Gliricidia maculata, 23.20 µm in Cassia nodosa, 28.22 µm in Pterocarpus marsupium and 31.20 µm in Erythrina suberosa.

12. All species have sieve tubes but the arrangement varies. The arrangement is stratified in Erythrina indica, E. suberosa, Gliricidia maculata, Pterocarpus marsupium and Sesbania grandiflora and non-stratified in Acacia farnesiana, Cassia fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Delonix regia, Hard wickia binata, Parkia roxburghii, Peltophorum pterocarpum, Prosopis juliflora, Samanea saman, Saraca indica and Tamarindus indica.

13. The arrangement of the rays is stratified in Gliricidia maculata, Peltophorum pterocarpum, Pterocarpus marsupium and Sesbania grandiflora and non-stratified in Acacia

farnesiana, C. fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Erythrina indica, E. suberosa, Delonix regia, Hardwickia binata, Parkia roxburghii, Prosopis juliflora, Samanea saman Saraca indica and Tamarindus indica.

14. The sieve-tube elements possess simple sieve plates on their end walls which are either almost transeverse or slightly inclined in Erythrina indica, E. suberosa, Gliricidia maculata, Pterocarpus marsupium and Sesbania grandiflora, whereas in Acacia farnesiana, Cassia fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Delonix regia, Hardwickia binata, Parkia roxburghii, Peltophorum pterocarpum, Prosopis juliflora, Samanea saman, Saraca indica and Tamarindus indica, have inclined end walls with compound sieve plates.

15. The mean proportion of sieve-tube elements in the conducting phloem ranges from 6.01% to 54.63% in the different species studied viz. 6.01% in Hardwickia binata, 7.19% in Cassia siamea, 8.35% in Peltophorum pterocarpum, 10.62% in Parkia roxburghii, 11.78% in Cassia javanica, 13.62% in Pterocarpus marsupium, 14.82% in Cassia fistula, 15.13% in C. nodosa, 15.80% in Sesbania grandiflora, 15.98% in Gliricidia maculata, 16.99% in Tamarindus indica, 17.40% in Cassia renigera, 20.37% in Erythrina suberosa, 20.78%

in Prosopis juliflora, 27.49% in Erythrina indica, 28.87%in Samanea saman, 29.04% in Acacia farnesiana, 40.79% in Saraca indica and 54.63% in Delonix regia.

16. The mean length of sieve-tube elements is greater in the species with non-stratified arrangement than those with stratified pattern, confirming the established evolutionary trend. The mean sieve-tube cell length measures 184.48 µm in Samanea saman, 189.76 µm in Gliricidia maculata, 190.40 µm in Pterocarpus marsupium, 194.56 µm in Sesbania grandiflora, 224.64 µm in Prosopis juliflora, 240 µm in Tamarindus indica 245.28 µm in Erythrina indica, 252.16 µm in Hardwickia binata, 259.20 µm in Cassia nodosa, 269.60 µm in C. renigera, 290.24 µmin Acacia farnesiana, 322.03 µm in Cassia fistula, 327.52 µm in Parkia roxburghii, 351.36 µm in Peltophorum pterocarpum, 353.16 µm in Erythrina suberosa, 353.22 µm, in Cassia siamea, 364 µm in C. javanica, 380.96 µm in Saraca indica and 445.28 µm in Delonix regia, whereas the width measures 17.92 µm in Pterocarpus marsupium 19.23 µm in Prosopis juliflora, 21.60 µm in Gliricidia maculata, 24.64 µm in Cassia fistula, 26.88 µm in Tamarindus indica, 27.78 µm in Peltophorum pterocarpum, 28.32 µm in Hardwickia binata, 28.80 µm in Cassia nodosa, 31.58 µm in C. siamea, 32 µm in Acacia farnesiana, 32.16 µm in Sesbania grandiflora,

32.80 µm in Cassia javanica, 34.05 µm in Parkia roxburghii, 34.56 µm in Erythrina indica, 35.55 µm in Saraca indica, 36.19 µm in Erythrina suberosa 38.30 µm in Delonix regia, 38.40 µm in Samanea saman and 40.16 µm in Cassia renigera.

17. The phloem rays are homogeneous having only procumbent cells in all the investigated species except Hardwickia binata in which they are homogeneous as well as heterogeneous.

18. The arrangement of rays is non-stratified in all the investigated species except Gliricidia maculata, Peltophorum pterocarpum, Pterocarpus marsupium and Sesbania grandiflora.

19. The rays are usually narrow in Cassia fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Delonix regia, Gliricidia maculata, Hardwickia binata, Parkia roxburghii, Peltophorum pterocarpum, Prosopis juliflora, Pterocarpus marsupium, Samanea saman, Saraca indica, Sesbania grandiflora and Tamarindus indica and broad in Acacia farnesiana Erythrina indica and E. suberosa.

20. The rays are cent percent narrowed i.e. 1-3 seriate in Cassia fistula, C. javanica, C. nodosa, C. renigera, C.

siamea, Hardwickia binata, Peltophorum pterocarpum, Pterocarpus marsupium, Saraca indica, Sesbanaia grandiflora and Tamarindus indica, 97% in Gliricidia maculata, 95% in Samanea saman, 77% in Prosopis juliflora and 59% in Delonix regia. In Acacia farnesiana, Erythrina suberosa, E. indica the rays are generally broad having 77%, 87% and 88% respectively.

21. The mean height of rays varies from 93.76 µm (5.74 cells) to 2384.80 µm (64.75 cells) in different species viz. 93.76 µm (5.87 cells) in Samanea saman, 126.40 µm (5.74 cells) in Sesbania grandiflora, 129.76 µm (8.06 cells) in Cassia renigera 130.56 µm (6.64 cells) in Pterocarpus marsupium, 147.20 µm (6.32 cells) in Gliricidia maculata, 148 µm (8.36 cells) in Cassia javanica, 172.80 µm (9.66 cell) in C. nodosa, 182.88 µm (10.76 cells) in Peltophorum pterocarpum, 186.11 µm(11.20 cells)in Tamarindus indica, 198.72 µm (9.66 cells) in Cassia siamea, 211.04 µm (10.59 cells) in C. fistula,230.08 µm (16.65 cells)in Prosopis juliflora, 246.72 µm (8.63 cells) in Hardwickia binata, 288.96 µm (16.29 cells) in Parkia roxburghii, 318.88 µm (12.50 cells) in Saraca indica 329.60 µm (23.12 cells) in Acacia farnesiana, 343.20 µm (17.18 cells) in Delonix regia, 1350.40 µm (47.40 cells) in Erythrina suberosa and 2384.80 µm (64.75 cells) in E. indica, whereas the width varies from

18.90 µm (1.18 cells) to 470.80 µm (12.10 cells) viz. 18.90 µm (1.18 cells) in Peltophorum pterocarpum, 20.64 µm (1.24 cells) in Cassia fistula, 27.36 µm (1.73 cells) in Hardwickia binata, 29.92 µm (2.18 cells) in Tamarindus indica,32.32 µm (2.22 cells) in Samanea saman, 34.56 µm (3.22 cells)in Prosopis juliflora, 36.32 µm (2.71 cells) in Cassia renigera, 36.48 µm (2.30 cells) in C. siamea, 37.44 µm (2.48 cells) in Pterocarpus marsupium, 38.40 µm (2.04 cells) in Gliricidia maculata, 38.88 µm(2.36 cells) in Cassia nodosa, 39.36 µm (1.70 cells)in Saraca indica, 41.60 µm(2 cells) in Sesbania grandiflora 51.04 µm (2.75 cells) in Parkia roxburghii, 51.84 µm (2.92 cells) in Delonix regia, 54.08 µm (4.04 cells) in Acacia farnesiana 297.60 µm (10.20 cells) in Erythrina suberosa and 470.80 µm (12.10 cells) in E. indica.

22. The rays are mostly short (1.10 cells) in Cassia fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Gliricidia maculata, Hardwickia binata, Pterocarpus marsupium, Samanea saman, Sesbania grandiflora, medium (11.20 cells) in Delonix regia, Parkia roxburghii, Peltophorum pterocarpum, Prosopis juliflora, Saraca indica and Tamarindus indica and tall (above 20 cells) only in Acacia farnesiana, Erythrina indica and E. suberosa.

23. Ray frequency varies from 1.56 to 71.57 rays/mm^2 in the conducting phloem zone of different species viz. Erythrina indica (1.56), E. suberosa (2.41), Acacia farnesiana (12.12), Delonix regia (15.60), Parkia roxburghii (29.55), Prosopis juliflora (30.92), Saraca indica (32.95), Sesbania grandiflora (37.48), Cassia nodosa (40.92), C. javanica (42.32), C. renigera (45.29), Hardwickia binata (50.12), Cassia siamea (53.26), Peltophorum pterocarpum (55.77), Cassia fistula (58.11), Tamarindus indica (61.29), Samanea saman (63.09), Pterocarpus marsupium (65.83) & Gliricidia maculata (71.57).

24. The area occupied by the rays is as high as 33.33% and as low as 10.08% in the conducting phloem in the species studies viz. 10.08% in Pterocarpus marsupium, 13.36% in Peltophorum pterocarpum, 13.61% in Cassia renigera, 14.48% in Prosopis juliflora, 14.96% in Cassia siamea, 15.05% in C. javanica, 15.15% in C. nodosa, 15.75% in Acacia farnesiana 17.19% in Hardwickia binata, 18.59% in Delonix regia, 19.02% in Cassia fistula, 19.63% in Samanea saman, 20.35% in Gliricidia maculata, 21.30% in Sesbania grandiflora, 22.82% in Saraca indica 24.92% in Parkia roxburghii, 25.15% in Tamarindus indica, 27.80% in Erythrina indica and 33.33% in Erythrina suberosa.

25. The area occupied by axial parenchyma in the conducting phloem has a wide variation from 18.72% to 65.74%: 18.72% in Delonix regia, 20.12% in Saraca indica, 36.82% in Acacia farnesiana, 37.85% in Samanea saman, 38.75% in Erythrina indica, 44.60% in Tamarindus indica, 45.33% in Sesbania grandiflora, 46.44% in Prosopis juliflora, 40.25% in Cassia nodosa, 52.57% in C. fistula, 53.58% in Gliricidia maculata, 54.42% in Parkia roxburghii, 56.43% in Cassia renigera, 61.05% in Peltophorum pterocarpum, 61.48% in Cassia javanica, 64.50% in C. siamea, 65.36% in Pterocarpus marsupium and 65.74 % in Hardwickia binata.

26. Brachy-type sclereids are found in the non-conducting phloem and phelloderm except Pterocarpus marsupium. The mean length of sclereids varies from 50.18 µm to 183.65 µm in investgated species viz. 50.18 µm in Prosopis juliflora, 57.52 µm in Gliricidia maculata, 54.15 µm in Samanea saman 54.78 µm in Acacia farnesiana, 61.88 µm in Hardwickia binata 63.20 µm in Parkia roxburghii, 69.60 µm in Sesbania grandiflora 67.76 µm in Tamarindus indica, 73.60 µm in Cassia renigera, 87.95 µm in Saraca indica, 90.75 µm in Delonix regia, 98.08 µm in Erythrina indica, 104.16 µm in Cassia fistula, 113.76 µm in C. nodosa, 123.20 µm in C. javanica, 124.64 µm in C. siamea

170.24 µm in Peltophorum pterocarpum, & 183.65 µm in Erythrina suberosa, whereas the width varies from 30.82 µm to 61.38 µm in various species studied viz. 30.82 µm in Cassia siamea, 33.47 µm in Prosopis juliflora, 34.40 µm in Cassia renigera, 34.52 µm in Acacia farnesiana, 35.84 µm in Cassia javanica, 36.64 µm in Delonix regia, 37.76 µm in Parkia roxburghii, 38.08 µm in Tamarindus indica, 41.98 µm in Cassia nodosa, 42.08 µm in Erythrina indica, 42.24 µm in Peltophorum pterocarpum, 42.90 µm in Saraca indica, 48.50 µm in Cassia fistula, 48.80 µm in Sesbania grandiflora and 61.38 µm in Erythrina suberosa.

27. The amount of sclereids in the non-conducting and phelloderm parts varies from 1.50% to 41.62% in different species viz. 1.50% in Hardwickia binata, 2.05% in Prosopis juliflora, 2.32% in Erythrina indica, 2.65% in Sesbania grandiflora, 3.04% in Erythrina suberosa, 4.12% in Parkia roxburghii, 9.11% in Acacia farnesiana, 9.74% in Cassia javanica, 10.55% in Samanea saman, 11.95% Cassia fistula, 13.18% in C. siamea, 13.57% in C. renigera, 16.48% in C. nodosa, 19.20% in Saraca indica, 26.38% in Peltophorum pterocarpum, 27.50% in Delonix regia and 41.62% in Tamarindus indica.

It is inferred from the present observations that the investigated taxa could be identified on the basis of their bark anatomy.

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CERTIFICATE

This is to certify that the thesis entitled "Studies on the bark anatomy of some cultivated trees" embodies original research work carried out by Mr. Kalimullah. It may be submitted to the Aligarh Muslim University, Aligarh towards the fulfilment of requirements for the degree of Doctor of Philosophy in Botany.

(ZIAUDDIN AHMAD)
SUPERVISOR

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CONTENTS

INTRODUCTION

In a broad sense, 'bark' means the outer hard crust of a tree-trunk, but in a technical sense, it means much more. To an anatomist, it commonly refers to all the tissues outside the vascular cambium (Esau, 1960) and in an old stem and root, include secondary phloem and periderm(s) In the primary plant body the bark constitutes the primary phloem, pericycle, cortex and epidermis. The external morphology and internal structure of bark exhibit different patterns.

Bark anatomy, particularly of forest trees, has been a neglected aspect of study in the past. It is only for the last two decades that the bark study, owing to its immense economic and taxonomic significance has been gaining increasing attention of the anatomists and is proving to be of help to foresters, botanists, taxonomists, pharmacognocists and forenisc experts in various ways.

Identification of plant species is so far based almost exclusively on their reproductive structures. At times,it becomes ticklish, if not entirely impossible, to make a proper identification of plants when they are devoid of flowers and foliage or when they have been felled and made into logs. The only thing that can be helpful at this juncture is the knowledge of their bark anatomy apart from

wood anatomy. One who is adequately aware of the bark features, can identify the various species just by casting a glance on pattern of their bark of stem. This is especially significant in forest practices.

Further, barks of several plants are significant from therapeutic point of view. Many such barks in fragmentary form are mixed with other similar looking bark and sold in the market in adultarated form. The original bark can be easily distinguished from the adulterants through anatomical investigation.

Zahur (1959) stressed upon the need of taking into account structural details of as many tissues as possible for an adequate and stable system of classification. As a consequence, a number of workers exploited the bark features for identification of certain economically important species. Thorenaar (1926), Symington (1943), Metcalfe and Chalk (1950), Wood (1952), Chang (1951, 1954a,b), Browne (1955) and Chattaway (1953, 1955a,b,c,d,e, 1959) are the pioneer workers in this field. Whitmore (1962a,b,c, 1963) was the first to exploit the bark morphology in the classification of Dipterocarpaceae and Fagaceae. Later works out comparative bark anatomy include those of Esau (1964), Ahmad et al. (1969), Patel (1975), Lotova (1976), Yunus (1976), Ghouse and Jamal (1978), Parameswaran and Zamuco

(1978), Datta (1981), Khan et al. (1982), Parameswaran & Conard (1982), Iqbal and Ghouse (1982, 1983), Esau (1984), Esau and Cheadle (1984), Outer (1986), Malychenko(1986, 1988), Malychenko and Lotova (1986), and Trockenbrodt and Parameswaran (1986). However, the information on bark features of taxonomic significance is still too meagre to be confidently employed for identification purposes.

On the Indian scene, study of bark anatomy especially with the Indian forest trees is very scanty. In India no such attempts have yet been made and thus the present problem concerning some cultivated leguminous trees may possibly be considered as one of the maiden attempts in this direction. The study pertains to the tree species found at Aligarh (Uttar Pradesh) and Bhopal (Madhya Pradesh) district and certain adjoining areas. On the basis of the information likely to emanate from this study it is intended to prepare a dichotomous key for the purpose of identification of these trees.

The following are the aspects that would mainly be covered in the present study:

(A) Macro-morphology of the bark

1. Colour of bark
2. Texture of bark (External appearance)
3. Type of bark (External structural features)

(B) Micro-morphology of the bark

1. Detailed study of secondary phloem
   (a) conducting phloem
   (b) non-conducting phloem
2. Study of rhytidome
   (a) Structure and position of periderm/s
   (b) Mode of shedding of bark.

MATERIALS AND METHODS

SELECTION OF SITE:

For the purpose of the study of bark, the cultivated leguminous trees are selected in and around Aligarh (Uttar Pradesh) and Bhopal (Madhya Pradesh) districts. It is therefore necessary to go into the geographical set-up, topography and mateorology of the regions as given below:

GEOGRAPHICAL SET - UP OF ALIGARH:

The Aligarh district lies in the North-West of Uttar Pradesh (North State of India) in the fertile agricultural plain of Ganga Jamuna Doab between 29° 29' N and 28° 11'N latitude and 77° 29' E and 78° 38' E longitude (Fig. 1).

GEOGRAPHICAL SET-UP OF BHOPAL:

The state of Madhya Pradesh, the largest state of India, is situated centrally and Bhopal is the capital of the state located in the hilly terrain of Vindhya range on 23° 16' N latitude and 77° 25' E longitude (Fig. 2).

TOPOGRAPHICAL SET-UP OF ALIGARH:

The soil of Aligarh district is of loam and clayey loam type with a very high pH value and very poor drainage

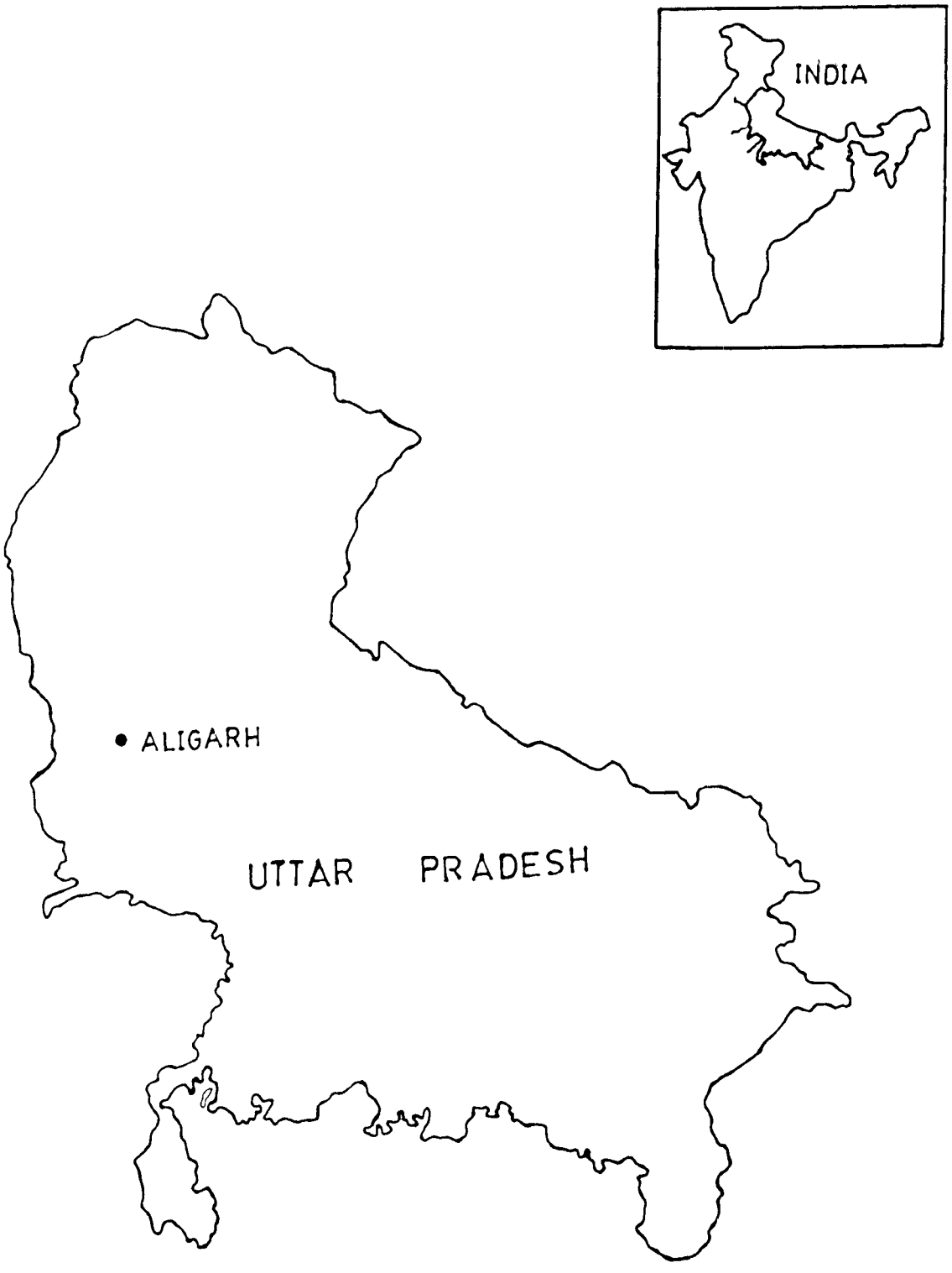


Fig.1

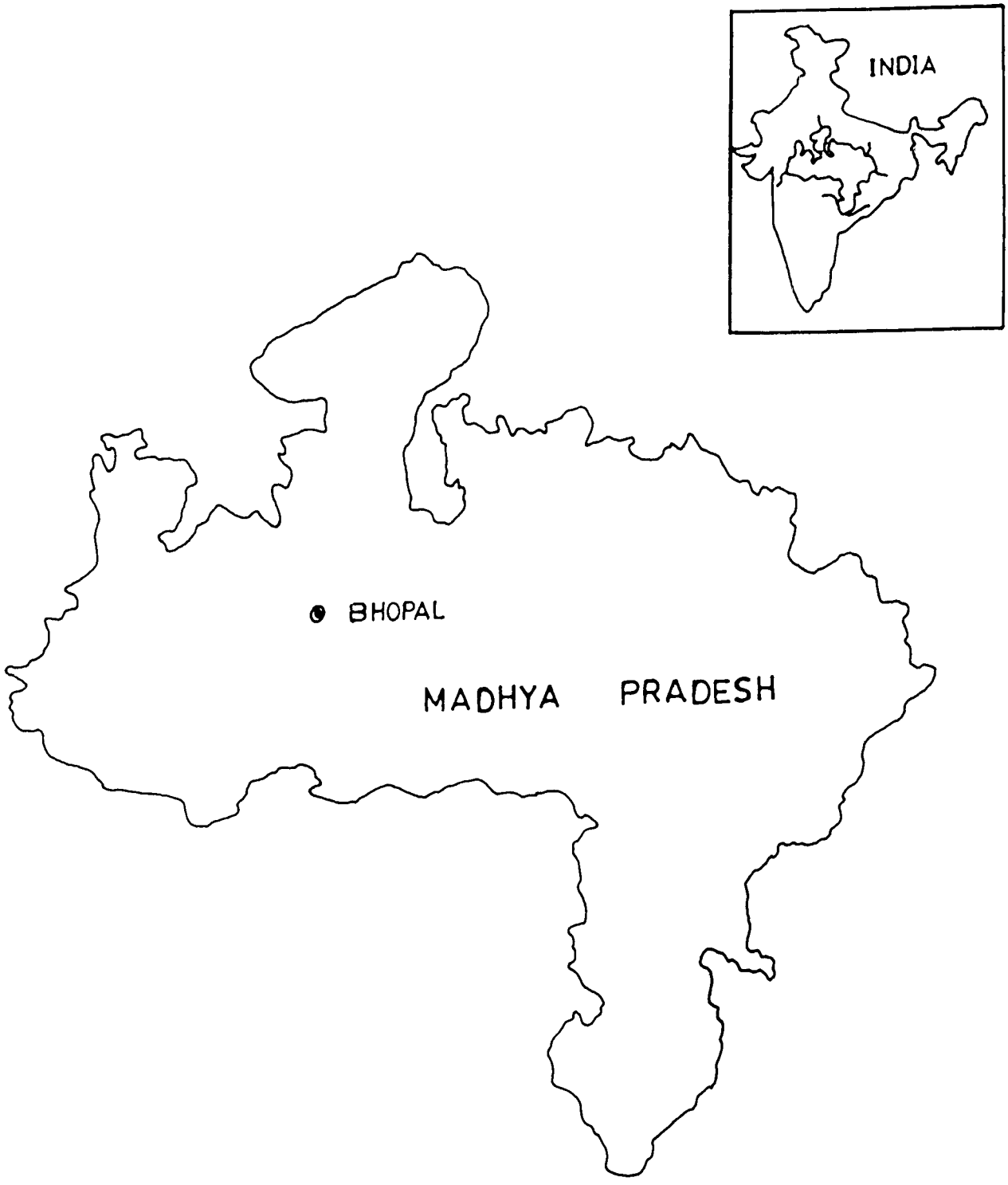


Fig.2

quality. The layers of loam and clayey loam lie upto the depth of 2.0 to 6.0 meters from the surface. The quality of clay is maximum in top layers and it decreases downwards. The soil in this region is ash-grey in colour, becoming black when moist.

TOPOGRAPHICAL SET-UP OF BHOPAL:

Major part of Bhopal lies on the Malva plateau, sloping towards the North except the South Valley. Topographically, the Malva Plateau presents undulating surface interspersed with areas of rich black-cotton soil. The hilly system is formed by the great Vindhya range along the southern scarps of the plateau and the spurs of the main chain. More than half of the area is concealed under soil and the main outcrops are seen in northern parts only. Two major types of soil found in the Bhopal region are; (1) Black-cotton soil (regur) derived from the Deccan trap by weathering. A major part of the plain area is under this thick soil. (2) Laterite soil with different grades and at few places somewhat sandy. This type of soil is well developed on the summits of hills.

METEOROLOGY OF ALIGARH:

Aligarh and the surrounding areas have a dry and tropical monsoon type of climate with seasons like winter, summer and monsoon.

WINTER SEASON:

The south-west monsoon starts declining in mid October and ceases by late November. The beginning of winter season is marked by a considerable fall in temperature to 20.6°C in November. December and January are the coldest months of the year during which the mean monthly temperature usually ranges between 8.5°C and 16.4°C. In these months the nights are very cold and the days are comparatively warmer with foggy mornings. The winds are dry and of continental origin. Occasional winter rains are brought about by the cold weather storms. The rain is irregular and sporadic (Table 1). By the end of February the temperature begins to rise.

SUMMER SEASON:

This season begins with March and continues till June. The beginning is heralded by an appreciable rise in temperature and decrease in pressure. Due to wide range of temperature during the summer months, the days are warm and nights are cooler. May and June are the hottest months with their mean temperature rising up to 35.8°C. Monthly average of the minimum and maximum daily temperatures is presented in Table 1. The days are characterised by heat and dry air, the relative humidity declining to 36.2% in May (Table 1). The rains are rare, sporadic, short lived and highly variable

in amounts, the total rain-fall during the summer being 1.6 mm (Table 1).

MONSOON SEASON:

The atmospheric temperature drops with the arrival of humid oceanic currents and the air becomes cool and pleasing by late June. In this season the average temperature falls to 33.0°C in June and 29.8°C in July (Table 1). The relative humidity increases from 57.9% in June to 77.6% in August (Table 1). The sky is generally overcast.

METEOROLOGY OF BHOPAL:

Bhopal and surrounding areas are generally treated as tropical region which observes a fairly heavy rainfall during the wet season, succeeded by a dry season. However, the climate of Bhopal is relatively moderate and dry except during the monsoon, indicating a seasonal rhythm. The year is divided into three major seasons viz., summer, monsoon and winter.

SUMMER SEASON:

This season begins with March and continues till June The beginning is measured by an appreciable rise in temperature and decrease in pressure. Due to wider range of temperature during the summer months, days are warm and nightare

pleasent. May and June are the hotest months with the mean temperature rising up to 32.4°C. Monthly average of the minimum and maximum daily temperatures is presented in Table 2. The days are characterised by heat and dry air, the relative humidity declining to 45.6% in May (Table 2). The rains are rare, sporadic, short-lived and highly variable in amounts. The rainfall during the summer varies from 0.2 mm to 4.5mm (Table 2).

MONSOON SEASON:

The rainy season in Bhopal and its surrounding areas usually starts from mid June and continues till August or September due to south-west monsoon. The average annual rainfall is recorded to be 3.6 mm approximately with about 30% of the precipitation occuring during June to Septmber. The average temperature remains 28.1°C in June to 26.8°C in July (Table 2). The relative humidity increases from 65.2% in June to 89.4% in August (Table 2). The sky is generally overcast in this part of the season.

The time of the onset and retreat of the monsoon varies from year to year. The rains generally set in by June or early July and continue till the end of September or October. The maximum rainfall recorded is about 14.2 mm in August (Table 2).

TABLE -1

MEAN MONTHLY TEMPERATURE (in°C), RELATIVE HUMIDITY (in %)AND RAINFALL (in mm) RECORDED AT METEOROLOGICAL DEPARTMENT, AMU, ALIGARH DURING 1984-1987

Month	Temperature	Relative Humidity	Rainfall
January	8.5 (6.8 - 21.0)	70.7	-
February	17.3 (7.8 - 26.9)	60.9	0.2
March	24.9 (14.8 - 34.9)	50.8	-
April	29.9 (21.4 - 38.4)	46.4	-
May	35.8 (27.7 - 44.0)	36.2	-
June	33.0 (26.9 - 39.1)	57.9	1.6
July	29.8 (26.0 - 33.6)	76.4	5.3
August	29.5 (25.6 - 33.7)	77.6	8.7
September	28.5 (23.2 - 33.8)	73.3	2.8
October	26.5 (18.2 - 34.8)	49.7	0.1
November	20.6 (12.1 - 29.3)	57.2	-
December	16.4 (8.4 - 24.5)	60.8	-

Figures within parentheses indicate the range.

TABLE - 2

MEAN MONTHLY TEMPERATURE (in°C), RELATIVE HUMIDITY (in %) AND RAINFALL(in mm) RECORDED AT METEOROLOGICAL DEPARTMENT,BHOPAL DURING 1984-1987

Month	Temperature	Relative Humidity	Rainfall
January	18.2 (10.5-23.4)	57 .8	0.1
February	21.0 (13.9-30.9)	40.2	1.4
March	25.0 (17.2-34.0)	32.8	-
April	28.8 (21.2-38.4)	18.2	-
May	32.4 (26.0-40.2)	45.6	0.2
June	28.1 (23.5-32.4)	65.2	4.5
July	26.8 (22.5-29.2)	86.1	9.8
August	26.2 (22.8-29.7)	89.4	14.2
September	24.9 (21.8-29.6)	84.5	11.4
October	23.4 (19.6-32.2)	76.0	2.6
November	19.5 (11.8-27.3)	47.7	-
December	17.6 (9.8-25.3)	53.5	-

Figures with parentheses indicate the mean of minimum and maximum values.

WINTER SEASON:

The southwest monsoon starts declining in mid October and ceases by late November. The beginning of winter season is marked by a considerable fall in temperature. December and January are the coldest months of the year during which the mean monthly temperature usually ranges between 17.6°C and 18.2°C. In these months the night are very cool and days are comparatively warmer with foggy mornings. The winds are dry and of continental origin. Occasional winter rains are brough about by the cold weather storms. The rain is irregular and sporadic (Table 2). By the end of February the temperature begins to rise (Table 2).

MATERIALS STUDIED:

The following nineteen cultivated leguminous trees in and around of Aligarh (Uttar Pradesh) and Bhopal (Madhya Pradesh) were identified for the purpose of the study:

Acacia farnesiana Willd.	Mimosaceae
Cassia fistula L.	Caesalpiniaceae
Cassia javanica L.	Caesalpiniaceae
Cassia nodosa L.	Caesalpiniaceae
Cassia renigera Wall.	Caesalpiniaceae
Cassia siamea Lam.	Caesalpiniaceae
Delonix regia Raf.	Caesalpiniaceae

Erythrina indica Lam.	Papilionaceae
Erythrina suberosa Roxb.	Papilionaceae
Gliricidia maculata Jacq.	Papilionaceae
Hardwickia binata Roxb.	Caesalpiniaceae
Parkia roxburghii G. Don	Mimosaceae
Peltophorum pterocarpum (DC) Backer exk. Hyene.	Papilionaceae
Prosopis juliflora DC	Mimosaceae
Pterocarpus marsupium Roxb.	Papilionaceae
Samanea saman (Jacq) Merr.	Caesalpiniaceae
Saraca indica L.	Caesalpiniaceae
Sesbania grandiflora Pers.	Papilionaceae
Tamarindus indica L.	Caesalpiniaceae

Acacia farnesiana Willd.

A thorny small tree, covered with minute pale brown dots on the stem, reaching a height of 15'. A native of tropical America, it is cosmopolitan in tropics and has spread itself throughout the greater part of India, Burma and Ceylon. It is often cultivated in gardens (Manjunath, 1948). The bark is used for tanning and dyeing leather. The gum exuding from the trunk is considered to be superior to gum arabic in arts (Dastur, 1962).

Cassia fistula L.

A moderate size deciduous tree with slender branches

and long shining compound leaves. Distributed in Bihar, Orissa, Uttar Pradesh, Maharashtra, Madras, Central and Eastern Himalayas to Ceylon and Malacca ascending to 1000mm in elevation, China, Malasysia and throughout India (Tiwari, 1979). It is common deciduous forests of India and Burma (Cowen, 1950). The bark known as sumari, yields good quality tannin but is apt to darken the leather too much. The root bark contains besides tannin, phlobaphenes and oxyanthra quinen which probably consists of a mixture of emodin and chrysophanic acid and can be used to cure black-water fever (Tiwari, 1979).

Cassia javanica L.

Medium to large size tree with grey or brown bark often thorny (Tiwari, 1979). This is a native of Java and known as Java cassia. Bark yields about 0.9 to 1.64 per cent of oil of which 80 per cent is cinnamic aldehyde (Sastri, 1950).

Cassia nodosa Ham.

A large evergreen tree among pink cassias with slightly pubescent, oblong to ovate leaflets. A native of Eastern Himalayas, Malacca, Malaysia and Philippines. It is distributed in different parts of India as Bihar, Orissa and Uttar Pradesh (Cowen, 1950). Cassia bark yields cinnamic

aldehyde, one of the most important oriental velatile oils (Sastri, 1950).

Cassia renigera Wall.

A medium size (up to 20 feet tall) deciduous tree known as Burmese pink Cassia (Cowen, 1950). Branches pubescent with raised lines running down from the base of the leaf, the youngest shoots silky (Tiwari, 1979). Distributed along the banks of the Irrawaddi (Burma) valley up to about 3000 ft. elevation in Madhya Pradesh and Uttar Pradesh (Tiwari, 1979).

Cassia siamea Lam.

A small evergreen tree, probably indigenous in Burma and in the southernmost part of the Western Peninsula, is cultivated throughout India and Burma (Brandis, 1971).

Delonix regia Raf.

A native of Madagascar, this medium size ornamental tree is planted in avenues and gardens throughout the warmer and damper parts of India. Introduced during the last 140 years to this region, it is common to Burma and Orissa (India) (Sastri 1952, Tiwari, 1979).

Erythrina indica Lam.

A medium size, fast growing deciduous tree reaching

a height up to 60 ft. Stem armed with conical prickles up to the third or fourth year (Sastri, 1952). Distributed throughout India, Pakistan and Andamans. The bark is used for tanning and dying. It yields a fibre suitable for cordage (Dastur, 1962).

Erythrina suberosa Roxb.

A medium size to large tree, 40 - 50 ft. high, with straight cylindrical bole (13-30 ft. in height and 3-6 ft. in girth) (Sastri, 1952). The tree is found scattered throughout the dry forests of India, form the Himalyas to Ceylon and Burma. It is often planted as an ornamental and a fence plant (Sastri, 1952). The fibre extracted from the bark is used for cordage (Dastur, 1964).

Gliricidia maculata Jacq.

A medium size spreading and charming tree. Introduced in India 1916 from Ceylon where it was brought in 1899 from South America as an ornamental shurb and for green manure (Tiwari, 1979). The tree is grown fairly widely in part of Madras, Mysore, Bombay and Travandrom up to an elevation of 3000 ft. (Sastri, 1956).

Hardwickia binata Roxb.

A handsome deciduous tree, up to 120 ft. in height

and 15 ft. in gifth, with a clean cylindrical bole 40-50 ft. in length, is found in the dry savannah forests of the Deccan Peninsula, Central India and part of Uttar Pradesh and Bihar. It is occasionally cultivated in the plains (Sastri, 1959). The strong bark fibres are used for preparing well ropes and other agricultural purposes. The bark is also a valuable tanning material (Dastur, 1962).

Parkia roxburghii G. Don.

A large handsome tree easily marked out by grey lenticellate bark and large feathery leaves (Tiwari, 1979). It grows fast, up to 20 cm in diameter (trunk) and 8 cm in height within a 5-7 years time (Tiwari, 1979). It is wild in Malaysia, cultivated elsewhere; Bihar, Orissa, Maharashtra and Assam (Tiwari, 1979). The bark is employed in making lotions for skin diseases and ulcers. The bark is also reported to be cyanophoric (Deshaprabhu, 1966).

Peltophorum pterocarpum (DC) Backer exk. Hyene.

A handsome tree, up to 24 m in height, found in coastal forests of the Andaman Island and grown in many parts of India for its ornamental value (Deshaprabhu, 1966). The bark contains 20.8% of a catechol type of tannin and 9.5% non tans, can be used for tanning purposes (Deshaprabhu, 1966). The bark is good for tanning leather specially when mixed with

myrobolans (Tiwari, 1979). It yields a dye which colours cotton yellowish brown (Deshaprabhu, 1966).

Prosopis juliflora DC.

A very variable, evergreen spiny or sometimes unarmed tree or shrub, with drooping branches, found either in a wild or cultivated state in the drier parts of India. It is a small tree which attains a height up to 20 m under favourable conditons and is often reduced to a shrub in very dry situations. It is low branching and bushy in form in the early stages, together with its excellent copping power, it forms a very suitable soil binder and wind breaker. It is also grown for shade and hedges (Krishnamurthi, 1969).

The bark exudes a gum, consisting of nearly smoooth, light yellowish brown, more or less opaque tears, which are translucent and glassy when fractured. The gum forms a somewhat adhesive mucilage and can be used as an emulsifying agent. It is also used in confectionery and is sometimes employed for mending pottery (Krishnamurthi, 1969).

Pterocarpus marsupium Roxb.

A moderate size to large deciduous tree, up to 30 m in hight and 2.5 m in girth with a straight clean bole. It is commonly found in hilly regions throughout the Deccan

Peninsula and extending to Gujarat, Madhya Pradesh, Uttar Pradesh, Bihar and Orissa (Krishnamurthi, 1969). In the bark of this species are sacs filled with a red astringent oily gum which is obtained by incisions in the bark and sold as East India Kino (Cowen, 1950).

Samanea Saman (Jacq) Merr.

A large, handsome and spreading tree, easily recognizable by its evergreen canopy. Frequently planted in groups as an avenue tree because of its ability to keep its symmetrical conformation in spite of prevailing winds. It is a tree of rapid growth, brought originally from central America to Ceylon and forwarded from there to India as its wood was considered to be of great value for railway and fuel. It often reaches a height of 90 ft. (Cowen,1950).

Saraca indica L.

A small beautiful evergreen tree (6-9 m high) with dense green broad circular crown and evergreen foliages. It is found wild along streams or in the shade of evergreen forests. It occurs almost throughout India up to an altitude of 750 m in the central and the eastern Himalayas and the Khasi, Haro and Lushai hills (Chadha, 1972). It is one of the most sacred trees both to Hindus and Budhists. Its bark is used in several preparations related to female troubles

(Tiwari, 1979). It is also used for internal piles and dysentry (Dastur, 1962).

Sesbania grandiflora Pers.

A small quick-growing tree attaining a height up to 8 m and a girth up to 0.6 m with a straight stem and spreading branches (Tiwari, 1979). A native of Malaysia, it is grown in many parts of India such as Punjab, Delhi, Bengal, Assam and the Andamans (Chadha, 1972).

It is grown for oranmental purposes and is valued as a food and a good fodder. It is grown as a support for pepper and betel vines as a shade plant for coconut seedlings, and as a wind break in banana fields. The bark yields good fibre and a gum and various plant parts have a medicinal value (Chadha, 1972).

Tamarindus indica L.

A very large and semi-evergreen tree with well shaped orbicular or slightly oblong crown (Tiwari, 1979). Distributed throughout India and Pakistan (Dastur, 1962). The bark is astringent, tonic and febrifuge. The ash obtained by heating the bark with salt in an earthen pot is given (one or two grain) in colic and indigestion; a mixture of this ash with water forms a gargle for sorethroat and a mouthwash for aphthous sores (Dastur, 1962).

METHOD APPLIED

MACRO MORPHOLOGY:

For the purpose of the present study, samples were collected from five healthy individuals of comparable age for each of the chosen species. The collections were made during December and January during when no cambial derivatives are produced. The bark, alongwith some sapwood was slashed out in the form of blocks of 10x5 cm^2 surface area from all the four sides (east, west, north and south) of the main trunks about one and half metres above the ground.

To examine gross anatomy, lateral surface of the bark was cut clean with a razor blade, moistened with water and examined with a hand lens. The transverse surface was studied after staining with KI but keeping it moist with water to reveal the required details the best.

The features thus studied include the bark thickness and the nature of the bark surface (the external appearance, colour and distribution of lenticels), periderm/rhytidome thickness, type of ray expansion tissue and proliferation of parenchyma.

MICRO-MORPHOLOGY:

The large blocks of bark were made into smaller once

of surface 2 cm^2, fixed in FAA, and later aspirated in order to facilitate easy penetration of the fixative into the deep lying tissues (Johansen, 1940). After a week the samples were transferred to a glycero-alcohol mixture.

For microscopic observation, the blocks of barks were suitably trimmed and sectioned on a Reicherts sliding microtome in transverse and tangential longitudinal planes at a thickness of 10-15 um. These sections were stained with appropriate stains (detailed below) and mounted in Canada balsam after dehydration with ethanol series (Sass, 1958).

The following stain combination were used;

1. Heidenhains haematoxylin and Bismarck brown/Safranin (Johansen, 1940) were used to stain the sections specially where photo-micrography was intended.

2. Tannic acid - ferric chloride and lacmoid combination was applied for the study of sieve elements. (Cheadle et al 1953)

3. Schulze's solution (chloro-zino-iodine) was used for determination of suberized tissues.

MACERATION:

For the detailed study of phloem components, especially the sieve-tube elements and phloem fibres, the bark samples

were macerated. The samples were cut into 1 mm thick tangential slices and treated with 5% HNO_3 solution at 45-50°C. The treatment was continued until the cells became loose enough to separate on tapping gently with a glass rod (Ghouse et al. 1974). The macerated material was then washed on a filter paper to remove acid effect. Staining with Haematoxylin or Bismarck brown was carried out, for phloem fibres and with tannic acid, ferric chloride and lacmoid for sievetube elements.

STRUCTURAL DETAILS:

Gross structure: The external appearance, colour, thickness of secondary phloem and rhytidome, position and number of periderm, orientation and frequency of lenticles, depth of the conducting and non-conducting phloem were the aspects studied.

Detailed structure: Composition of rhytidome/periderm and secondary phloem is detailed below:

One hundred elements of sieve-tube and equal number of phloem fibres were measured with ocular micrometer scale in tangential longitudinal sections and macerate respectively and expressed in μm.

One hundred phloem rays in the conducting zone were measured randomly in tangential longitudinal section in terms

of number of cells and also in μm. For the sake of convenience, rays of varying heights have been categorized as short (1-10 cells),medium (11-20 cells) and tall (above-20 cells),whereas those of varying width, as uniseriate,biseriate,triseriate, tetraseriate and multiseriate rays. The frequency of rays was calculated with the help of squarish ocular scale and expressed in number per mm^2.

ESTIMATION OF COMPONENT PHLOEM TISSUES

The relative proportion of different component tissues in the conducting secondary phloem was determined on the basis of the area occupied by each component. This was calculated by the method adopted by Ghouse & Iqbal(1975). The procedure involves camera lucida drawings of the various components tissues on tracing paper of uniform thickness in about 20 randomly replicated microscopic fields. The sets of papers bearing the drawings were weighed on a sensitive microbalance before and after the removal of the areas occupied by different component tissues.The amount of different types of phloic components was later calculated in percentage on the basis of weights thus obtained as indicated below:

$$R = \frac{W_1 - W_2}{W_1} \times 100$$

W_1 = Weight of the tracing papers bearing drawings of all phloem components.

W_2 = Weight of the papers bearing the drawings of the given component tissue.

R = Relative proportion of a given component tissue.

The distribution patterns of fibres, rays and sclereids in the region between cambium and periderm were noted with the help of camera lucida drawings of cross sections at 50 x.

OBSERVATIONS

ACACIA FARNESIANA WILLD.

Macro-morphology

The bark is dark brown to black, soft, smooth in appearance(Plate 1A) with pungent (garlic) smell. The rhytidome is thin and has only a superficial periderm which runs more or less parallel to cambium. The ray expansion is fusiform, small wedge shaped (Fig. 3A). Lenticels are clearly visible and oriented horizontally on the entire bole surface (Plate 1A). The number of lenticels per cm^2 is estimated to be about 7.5 lenticles.

When the bark is blazed out, it is pale yellow which later changes into brownish colour on exposure. The exfoliation of the bark occurs in the form of scales with an average thickness of 0.5 mm and size of 2.77 x 1.54 mm^2.

Micro-morphology

The total bark thickness is of the order of 3 mm in the tree trunk circumference of 35 cm. The rhytidome is about 1 mm thick and constitutes 33.33% of the entire bark, whereas the secondary phloem measures about 2 mm accounting to 66.67% of the entire bark (Table 3).

The rhytidome is made up of single superficial periderm. They run around the entire circumference. The rhytidome cracks at the place of lenticels. The periderm has the usual three clear zones, phellogen, phellem and the phelloderm. The phellogen is single layered with almost rectangular cells in cross section. Phellem is multilayered zone of thick walled large suberized cells, which are flattened radially and arranged in compact radial tiers without intercellular spaces. The phelloderm is also a multi-layered zone, the cells of which have thin, non-suberized walls. These squarish and ractangular parenchymatous cells have inter-cellular spaces and are arranged more or less in radial rows. The phelloderm cells are almost of the same size as those of phellogen.

The secondary phloem is clearly differentiated into the conducting and the non-conducting zones. The average depth of the conducting zone is 0.6 mm which constitutes 28% of the total secondary phloem and 18.67% of the total bark, whereas the depth of the non-conducting zone is calculated to be 1.4 mm making 72% of the entire secondary phloem and 48% of the total bark (Table 3 & 4).

The microscopic observations on cross section of

the conducting phloem reveal that the fibres are arranged in continuous tangential bands except where rays are present (Fig. 11A). Between two such adjacent bands of fibres fascicles are present other components of phloem, i.e., the sieve-tube elements accompanied with companion cells and axial parenchyma, while the radially running rays pass almost straight in the conducting zone and in the non-conducting phloem, the rays become dilated (Fig. 11A). The non-coducting zone of phloem is distinuighed in having almost obliterated sieve elements and companion cells in addition to sclereids. The ray expansion tissue is a prominent feature of the non-conducting phloem (Fig. 11A).

The fibres are thick-walled and well lignified.They occur as the major component of the secondary phloem and are arranged in continuous tangential bands in the conducting phloem (Fig. 11A). However, their continuity breaks in outer bark due to proliferation and ray expansion tissues (Fig. 11A). Each fibre band is 3-7 cells wide in transectional view. The fibres constitute about 18.39% transectional area of the total conducting phloem (Table 5). Study of individual fibres in macerated materials, revealed that their apices are smooth and tapering, though at times with serrated and bifurcated (Fig. 20A). The length of fibres varies from 832 to 1664 µm with an average of 1198.56 µm,

whereas the width from 16.50 to 33 µm with an average of 20.77 µm (Table 6).

The sieve-tube elements are characterized by compound sieve plates born on deeply inclined end walls (Plate 1B). The lateral sieve areas occur on their latral walls (Plate 1B). The sieve-tube elements are arranged in a non-stratified order in tangential longitudinal plane. The length of sieve-tube elements ranges from 198 to 379.50 µm with an average of 290.24 µm, whereas their width varies from 16.50 µm with an average of 32.00 µm (Table 7). They occur in groups of 4-9 cells and occupy 29.04% area of the conducting phloem in transectional plane (Plate 1C & Table 5).

The axial parenchyma are comparatively smaller in size than the sieve-tube elements in crosssectional view. They occur around the sieve-tube elements and associated companion cells (Plate 1C). They form about 36.82% area of the conducting phloem in cross-section (Table 5). The parenchyma cells are not found to contain tannins in the conducting and non-conducting regions.

The rays are homogeneous in nature as they are composed of only procumbent cells. The rays are invariably tetra to multiseriate. They mostly take a deflected course

as they enter the non-conducting zones. The ray cells do not multiply in the conducting phloem. However, in the non-conducting region the rays undergo cell multiplication and form ray expansion tissue (Fig. 11A). The phloem rays occupy about 15.75% area of the conducting phloem in transectional plane (Table 5). The ray height ranges from 8 to 35 cells with an average of 23.12 cells (329.60 µm), whereas the width ranges from 4 to 5 cells with an average of 4.04 cells (54.08 µm) (Table 8). With regard to the frequency of the rays of varying height in the conducting zone, short rays constitute 12.5%, medium 25% and tall 62.5% of the total ray population (Table 9). Similarly, the biseriate rays are 6%, triseriate 17%, tet-raseriate 30% and multiseriate 47% (Table 10) and the frequency of seriation of ray per mm^2 reveals that the biseriates are 1.60 triseriates 2.67, tetraseriate 2.67 and multiseriates 4.28 per mm^2 (Table 11).

Sclereids are totally absent in the conducting phloem, but they occur in the non-conducting phloem in the form a tangential band (Fig. 11A). Sclereids are of brachy-type (Fig. 20A). The length of the sclereids ranges from 24.75-64 µm with an average of 34.52 µm (Table 12). The area occupied by sclereids in the non-conducting phloem and phelloderm was observed to be about 15.75% (Table 13).

CASSIA FISTULA L.

Macro-morphology

The bark is greyish green, smooth, soft and unfissured in young stem of upper parts and branches. It turns rough rugose and deep fissured in the trunk, (Plate ID) The fissures are V-shaped and ray expansion tissue is seen as tall broad wedges commencing from the outer part of the non-conducting region of secondary phloem up to the periderm (Fig. 3B). The rhytidome is thick and includes successive periderm layers that run slightly parallel to cambiuim and later deviate outwordly. Lenticel are not visible.

The bark when blazed, raddish juice oozes out. The outer bark is gree-nish and the deeper part has flesh colour which does not change even on exposure for a few days. The bark is flaked out irregularly in patches of 48.2 x 26.0 mm^2 surface with a thickness of 6.8 mm on the average.

Micro-morphology

The total thickness of the bark in a trunk of 70 cm circumference is 18.5 mm. The rhytidome measures about 6.8 mm and forms 36.76% of the total bark, whereas the total

thickness of the secondary phloem is about 11.7 mm which constitutes 63.24%of the total bark (Table 3).

The rhytidome consists of a superficial periderm with deep cracks. Of the usual three component regions of the periderm, the phellogen is single layered with rectangular cells in cross-sections, phellem is a narrow zone of thick-walled suberized cells which are somewhat flattened radially and arranged in compact radial rows, and the phelloderm is many layered the cells of which have non-suberized walls and are arranged in radial tiers. The cells are squarish/rectangular, and parenchymatous, with inter-cellular spaces. The phelloderm cells are about twice as large as the phellem cells. A large number of sclereids in groups of varying magnitude are observed among the phelloderm cells and in the non-conducting phloem (Fig. 11B).

The secondary phloem is not so deep yet clearly distinguishable into conducting and non-conducting zones. The average depth of the conducting zone is 0.7 mm which accounts for 5.98% of the entire secondary phloem and 3.78% of the entire bark, whereas the depth of the non-conducting zone is found to be 11.0 mm constituting 94.02% of secondary phloem and 59.49% of the entire bark (Table 3 & 4).

The microscopic study of the conducting phloem in cross sections reveals that the fibre groups are radially extended and are arranged in an irregular fashion. Between the fibre fascicles are present the sieve-tube elements with their associated companion cells and axial parenchyma. The radially running mostly narrow rays pass almost straight up to the limit of conducting phloem. The non-conducting phloem, on the other hand, possessed obliterated or crushed sieve-tube elements and companion cells, sclereids, and the dilated rays which deviate in their path as they approach the outer edge of the phloem. The axial parenchyma contains tannin.

The fibres are thick-walled and lignified. They appear as a major component of secondary phloem and are scattered in groups of varying sizes (Fig. 11B). Each group is 2-7 cells wide in transectional plane. The fibres form about 13.59% cross sectional area of the conducting phloem (Table 5). The individual fibre, examined in macerated form is usually normal. It is only at times the apices are dented and serrated (Fig. 20B). The length of fibres ranges from 368-1280 μm with an average of 839.52 μm, while the width from 16.50 μm to 33 μm with an average of 19.68 μm (Table 6).

The sieve-tube elements are characterized compound sieve-plates situated at inclined end walls (Plate I E). Sieve-areas are also prominent on lateral walls of the elements (Plate I E). The elements are arranged in a non-stratified pattern as seen in tangential longitudinal plane. The length of sieve-tube elements ranges from 160 to 456 µm with an average of 322.03 µm, whereas their width ranges from 16.50 to 35.20 µm with an average of 24.64 µm (Table 7). The elements are arranged in groups of 3-9, alternating with fibre bands, and occupy 14.82% of cross sectional area of the conducting phloem (Plate I F and Table 5).

The axial parenchyma is comparatively smaller in size than the sieve-tube elements in transverse sections. It does not show any definite pattern of arrangement but occurs mixed with phloem fibres, sieve-tube elements and companion cells (Plate I F), and form about 52.57% area of the conducting phloem (Table 5). These cells are devoid of tannins both in conducting and non-conducting phloem.

The rays are homogeneous in nature as they are composed of only procumbent cells. The rays are uniseriate and biseriate. They take almost straight radial run in the conducting phloem but adopting deflect in the non-conducting phloem. A few rays in the non-conducting phloem and axial parenchyma cells

resort to proliferation, right upto the periderm due to the strain and stress caused by increasing circumference (Fig. 11B). Tannin is found in the ray cells of both the conducting and non-conducting phloem. The rays occupy about 19.02% area of the conducting phloem in transectional view (Table 5). The height of the rays ranges from 5 to 20 cells with an average of 10.59 cells (211.04 µm), while the width covers 1 to 2 cells with an average of 1.24 cells (20.64 µm) (Table 8). In the conducting phloem frequency of the rays in respect of their height is calculated to be 55.1%, 41.4% and 3.5% for short, medium and tall rays respectively (Table 9). Similarly, the uniseriate rays are 83% and biseriate 17% (Table 10). On the other hand the frequency of uniseriate and biseriate rays per mm^2 in tangential longitudinal view in the conducting phloem of the uniseriate rays figures at 48.12 per mm^2 and biseriate 9.99 per mm^2 (Table 11).

The sclereids are completely absent in the conducting phloem, but appear in the non-conducting phloem in the form of groups of various shapesand sizesin addition to fibre groups and are brachy-type(Fig. 20B). They occupy 11.95% of the total area of the non-conducting phloem and phelloderm (Table 13). The length of the sclereids ranges from 24 µm to 272 µm with an average of 104.16 µm, whereas the width from 16.50 to 57.75 µm with an average of 48.5 µm (Table 12).

CASSIA JAVANICA L.

Macro-morphology

The bark is grey or greyish brown, soft, scaly and nearly smooth (Plate IIA). The lenticels reddish in colour and placed horizontally, are hardly visible, being about 8.73 lenticels per cm^2. Rhytidome is thin and includes single superficial periderm layer. The ray expansion tissue is small, narrow and compound wedge-shaped (Fig. 3C). It commences from the outer part of the non-conducting regions of secondary phloem and reaches the periderm.

When the bark is balazed, it looks green and turns reddish brown on exposure. Bark exfoliates as thin irregular scales with an average thickness of 0.5 mm and a surface of 1.7x1 mm^2, and even as powder.

Micro-morphology

The bark has a thickness of 7.7 mm in a tree trunk of 80 cm circumference. The rhytidome measures about 0.5 mm and forms 6.49% of the total bark, whereas the overall thickness of secondary phloem reaches about 7.2 mm thus constituting 93.51% of the total bark (Table 3).

The rhytidome consists of superficial periderm. The periderm as usual comprises the phellogen, phellem and phelloderm. The single layered phellogen contains rectangular cells. The phellem constitutes a narrow zone of suberized cells which are thick walled, almost flattened radially and arranged in compact radial rows. The phelloderm forms the largest area of the periderm and consists of squarish, rectangular cells with thin non-suberized walls, and arranged in radial rows leaving intercellular spaces. These cells are about 2 times larger than the phellem cells. A large number of clusters of sclereids are dispersed among the phelloderm cells (Fig. 12A). The lenticels are not visible.

The secondary phloem is differentiated into the conducting and the non-conducting zones. The average depth of the conducting phloem measures about 0.7 mm which forms 9.72% of the total secondary phloem and 9.09% of the total bark, whereas the depth of non-conducting zone is found to be 6.5 mm thus constituting 90.28% of the secondary phloem and 84.42% of the total bark (Table 3 & 4).

A detailed study of the conducting phloem reveals that fibres are scattered in fascicles of varying sizes. The sieve-tube elements with their associated companion

cells and axial parenchyma are also found irregularly distributed. The fine/narrow rays run radially straight in the conducting phloem (Fig. 12A). The non-conducting phloem, on the other hand, consists of obliterated sieve-tube elements and companion cells, sclereids and dilated rays which get slightly deflected in path.

The fibres are the most significant component of the secondary phloem.They are grouped, but do not show any regular pattern of arrangement (Fig. 12A). Each fibre group is 2-13 cells wide in transectional view. The fibres form about 11.69% area of the total conducting phloem in cross section (Table 5). At times the fibres have serrated, forked and dented apices (Fig. 20C). The length of fibres ranges from 280.50 µm to 973.50 µm with an average of 650.88 µm, whereas the width ranges from 16.50 µm to 33 µm with an average of 20.0 µm (Table 6).

The sieve-tube elements are characterized by compound sieve-plates, borne on deeply inclined end walls (Plate IIB). Slime plugs are observed on the end walls adhering to the sieve pores. Lateral sieve areas are also conspicuous on their lateral walls (Plate IIB). The sieve elements are arranged in a non-stratified manner. The length of sieve-tube elements ranges from247.50 µm to

495 µm with an average of 364 µm, while the width from 24.75 µm to 41.25 µm with an average of 32.80 µm (Table 7). The sieve elements are scattered in distinct groups of 2-6 cells, and occupy 11.78% area of the conducting region in transectional view (Plate IIC and Table 5).

The axial parenchyma surround the groups of sieve elements and associated companion cells. They are comparatively smaller in size than the sieve-tube elements in cross-section (Plate IIC) and form about 61.48% of the total transectional area of the conducting phloem(Table 5). The parenchyma cells contain tannins in the non-conducting phloem zone.

The rays are homogeneous in nature and possess only procumbent cells. These are uni to tri-seriate. They mostly get deflected as they enter the non-conducting phloem zone. Marked deflections of rays take place because of the disturbance caused by multiplication and proliferation of ray cells in the non-conducting phloem, which gives rise to small but wide wedge-shaped ray expansion tissue (Fig. 3C). The ray cells contain tannins in the non-conducting phloem. But the cells of the conducting phloem are totally devoid of tannins. The phloem rays are non-stratified and occupy about 15.05% area of the conducting phloem in transectional view (Table 5). The

ray height ranges from 4-13 cells with an average of 8.36 cells (148 µm), whereas the width from 1-3 cells with an average of 2.40 cells (39.20 µm) (Table 8). The frequency of rays with respect to height in the conducting phloem zone differs; the short rays form 83.30% and the medium rays 16.7%, while tall rays are nil (Table 9). Similarly, the uniseriate rays form 12%, biseriate 53% and triseriate 35% (Table 10). The frequency of rays of different width reveals that the uniseriate rays number 4.99, biseriate 22.34 and triseriate 14.99 per mm^2 (Table 11).

The sclereids are totally lacking in the conducting phloem, but appear in the non-conducting region in addition to fibre groups. The brachy-sclereids are found in the form of fascicles of varying magnitude (Fig. 20C & 12A). The sclereid length ranges from 40 µm to 272 µm with an average of 123.20 µm, whereas width ranges from 16.5 µm to 66 µm with an average of 35.84 µm(Table 12). The sclereids occupy about 9.74% area of the total non-conducting phloem and the phelloderm (Table 13).

CASSIA NODOSA L.

Macro-morphology

The bark is dark brown to blackish in colour, soft, scaly and almost smooth (Plate IID), associated with minute whitish lenticels which are visible and placed vertically. The rhytidome is very thin. The ray expansion tissue is found as a large broad wedges commencing from the outer part of the non-conducting region of secondary phloem to the periderm (Fig. 4A).

When the bark is blazed, a red juice exudes with pungent smell and hardens in a red astringent gum. The blaze shows green under the outer bark and red in the inner. The red colour changes into reddish brown on exposure to air. The bark peels off in the form of small and thin irregular pieces of average surface area of 7.29x4.44 mm^2 and thickness of 1mm. Hence the surface looks smooth (Plate IID).

Micro-morphology

The bark, as a whole measures 14.5 mm in thickness in a tree trunk having a circumference of 116 cm. The rhytidome measures about 0.5 mm in depth and forms 3.45% of the total bark, whereas the over all thickness of secondary phloem is 14.0 mm which constitutes 96.55% of the

total bark (Table 3).

The rhytidome is composed of just one superficial periderm. The periderm encircles but is interrupted at places by the formation of lenticels. The greater part of the rhytidome which is outside the peri-derm is consisted of dead secondary phloem. Through the phellem together with some part of dead secondary phloem bark sloughs off in minute thin irregular scales and even as powder. The lenticel is composed of filling or complementary tissues with a limting layer. The periderm is made up of usual phellogen, phellem, and phelloderm. The phellogen appears to be single layered and phellem constitutes a narrow zone of thin walled suberized cells in transectional view. These cells are somewhat flattend radially and arranged in compact radial rows. The phelloderm is multilayered, the cells of which possess non-suberized walls. They are more or less spherical with intercellular spaces and arranged in radical rows. A large number of sclereids occur amongst the phelloderm cells in groups of various shapesand sizes.

The secondary phloem is differentiated into conducting and non-conducting zones. The average depth of the conducting zone is 2.5 mm and constitutes 17.86% of the secondary phloem and 17.24% of the total bark, whereas the

depth of the non-conducting zone is found to be 11.5 mm constituting 79.31% of the total bark (Table 3 & 4).

The microscopic study further reveals that the secondary phloem fibres form large groups of different sizes, but not a tangential band (Figure 12A). In addition to fibres there are sieve-tube elements with their associated companion cells and axial parenchyma. The narrow rays run radially straight in the conducting phloem (Fig. 12A). The non-conducting phloem, on the other hand, differs in having obliterated or crushed sieve-tube elements, crushed or cleared companion cells, sclereids and dilated rays, which run radially straight for a short distance before taking a wavypath in the outer zone (Fig. 12A).

The fibres, the major component of secondary phloem occur in large groups of different sizes and constitute about 22.4 7% of the total cross-sectional area of the conducting phloem (Table 5). Each fibre group is 3-8 cells wide in transectional view. The fibre apices are generally smooth and tapering and occasionally they bear serrated, dentated or forked ends (Fig. 21A). The length of fibres varies from 346.50 µm to 1023 µm with an average of 637.76 µm, whereas the width ranges from 16.50 µm to 33 µm with an average of 23.20 µm (Table 6).

The sieve-tube elements have compound sieve plates, borne on oblique end walls (Plate IIE). Sieve areas are conspicuous on lateral walls (Plate IIE). The sieve elements are arranged in a non-stratified order. The length of sieve-tube elements ranges from 165 µm to 396 µm, with an average of 259.20 µm, while the width varies from 24.75 µm to 33 µm with an average of 28.80 µm (Table 7). The sieve elements occur in small groups of 2-4 elements or are isolated (Plate IIF). They occupy 15.13% area of the conducting region in transectional view (Table 5).

The axial parenchyma cells are comparatively much smaller than sieve-tube elements in transectional view. They occur among the sieve-tube elements (Plate IIF) and form about 47.25% cross sectional area of the conducting phloem (Table 5). The parenchyma cells contain tannins both in the conducting and the non-conducting zones.

The rays are homogeneous in nature being composed of only procumbent cells, and are uni to triseriate. In the transections, the rays run almost straight in the conducting zone and take a deflected pathway only in the non-conducting zone. Only, a few ray cells multiply and proliferate in the non-conducting phloem near the periderm, to give rise to the large broad ray expansion tissue

(Fig. 12A). The ray cells do not contain tannins in both the conducting and as well as non-conducting zones. The phloem rays occupy about 15.15% area of the total conducting phloem in transectional view(Table 5). The ray height ranges from 3 to 25 cells with an average of 9.66 cells (172.80 µm), whereas, the width varies from1 to 3 cells with an average of 2.36 cells (38.88 µm) (Table 8). With regard to the frequency of the rays of different heights in the conducting zone, the short rays constitute 53.40%, medium 43.3 % and tall 3.3 % of the total number of rays (Table 9). Similarly, the uniseriate rays form 5%, biseriate 40% and triseriate 55% of the ray population (Table 10). As to the frequency of different types of rays per mm^2, the uniseriate rays number 2.18, biseriate 16.25 and triseriate 22.49 per mm^2 (Table 11).

The sclereids are totally absent in the conducting phloem. But they appear in the non-conducting region in addition to fibre groups. They form fascicles of varying magnitude or occur as isolated elements (Fig. 12A). Sclereids are brachy-type (Fig. 12A). The length of the sclereids ranges from 33 µm to 248 µm with an average of 113.76 µm, whereas their width varies from 24.75 µm to 99µm with an average of 41.98 µm (Table 12). The amount of sclereids in the non-conducting region and the phelloderm is about 16.48% (Table 13).

CASSIA RENIGERA WALL.

Macro-morphology

The bark is black, hard, rough, longitudinally and tangentially fissured (Plate IIIA). The rhytidome is very thick and includes several periderm layers that deviate outwards (Fig. 4B). The ray expansion tissue looks like small broad wedges at the base of cracks commensing from the outer non-conducting region of the secondary phloem (Fig. 4B). The lenticels are deeply situated in the fissures and hence are discernible superficially.

When the bark is blazed, it exposes the deep reddish brown inner bark and dark red brown outer bark. The outer bark crust consisting of compact rhytidome sloughs off in the form of hard and thick flakes of varied dimensions with an average thickness of 6.3 mm and surface area of 43.1x21.5 mm^2.

Micro-morphology

The bark as a whole measures 24 mm in thickness in a tree trunk having a circumference of 10.6 cm. The rhytidome region measures about 18.2 mm in thickness and forms 75.83% of the total bark, while the secondary phloem is about 4.8 mm thick and constitutes 20% of the total

bark (Table 3).

The thick rhytidome comprises several discontinuous periderm layers leaving only one periderm around the entire circumference. This discontinuity of the outer periderm is caused by the pressure exerted by increasing bole circumference which results in the formation of fissures of various depths and sizes. Structurally, each periderm comprises phellogen, phellem and phelloderm. In cross sections, the phellogen is single layered and its cells are more or less rectangular in outline. Phellem is a corky, multi layered zone of rather thin walled, large, and somewhat flattened suberized cells arranged in compact radial rows. The phelloderm is also many layered and the component cells are composed of thin non-suberized walls. They are almost spherical parenchymatous cells with intercellular spaces and do not form radial rows as the phellem cells do. Most of the phelloderm cells contain tannins. They are slightly larger than the phellem cells. Sclereids are found in groups of varying size and as isolated cells in the phelloderm. Besides, there is a tangential band of sclereids below the phelloderm (Fig. 13A).

The secondary phloem can be separated into two different zones, i.e. the conducting and the non-conducting zones. The average depth of the conducting zones is 1 mm

which forms 17.24% of the entire secondary phloem and 4.16% of the total bark, whereas the non-conducting zone measures 4.8 mm, constituting 82.76% of the secondary phloem and 20% of the total bark (Table 3 & 4).

The microscopic study of the conducting zone shows that fibres occur in large groups of different sizes. But these groups are not arranged in distinct rows and remain somewhat randomly distributed. Between the fibre groups are located sieve-tube elements with associated companion cells and axial parenchyma. The rays are narrow and run radially, almost straight up to the non-conducting phloem. The rays have a tendency to disappear abruptly, an uncommon feature. The non-conducting zone differes in having obliterated or crushed sieve-tube elements, crushed or cleared companion cells, sclereids and dilated rays tending to resort to deflections.

The phloem fibres are thick-walled and well lignified. They occur as the principal mechanical elements of the secondary phloem and are scattered in big groups of different sizes (Fig. 13A). Each fibre group is 3-6 cells wide in transectional view. The fibres on the whole, occupy 12.56% of the conducting zone (Table 5). Fibre apices may be either smooth and tapering or may show diverse

manifestations such as segmention (Fig. 21B). The length of fibre elements ranges from 364.5 µm to 891 µm with an average of 592.80 µm, and the width varies from 16.50 µm to 33 µm with an average of 19.84 µm (Table 6).

The sieve-tube elements possess compound seive-plates on inclined end walls (Plate IIIB).The sieve areas on lateral walls are poorly developed (Plate IIIB).The sieve-tube elements are arranged in a non-stratified manner. The length of sieve-tube elements measures from 165 µm to 396 µm with an average of 269.60 µm while the width varies from 24.75 µm to 49.50 µm with an average of 40.16 µm (Table 7). The sieve elements occur in definite groups of 2-9 cells, lying between axial parenchyma (Plate IIIC).The area occupied by the sieve-tube elements in the conducting zone is estimated to be about 17.40% (Table 5).

The axial parenchyma cells are much smaller in size than sieve-elements as seen in transection and surround the groups of sieve elements. In addition to this, one to three cells deep the parenchyma tissue also occurs above and below the fibre groups (Plate IIIC).Most of the parenchyma cells, both in the conducting and the non-conducting zones of secondary phloem, contain tannins. The axial

parenchyma occupy about 56.43% of the total transectional area of the ocnducting phloem (Table 5).

The rays are homogeneous in nature, as they are composed of only procumbent cells. The rays are uniseriate to triseriate. They run almost straight radilly both in conducting and non-conducting zones up to the middle of non-conducting zone. Thereafter they take a deflected run. The ray cells contain tannins throughout the secondary phloem. The transectional area occupied by phloem rays constitutes 13.61% of the total conducting phloem (Table 5). The height of the rays varies from 2-12 cells with an average of 8.06 cells (129.76 μm) whereas the width varies from 1-3 cells with an average of 2.71 cells (36.32 μm) (Table 8). As to the frequency of the rays of varying height in the conducting phloem, the short rays are 92% and the medium ones 8% of the total number of rays (Table 9). The uniseriate rays make 10%, biseriate 34% and triseriate 56% of the total ray population (Table 10). In contrast, when the frequency of different types of rays is calculated in terms of number of rays per mm^2 in the conducting zone, the uniseriate rays are 4.52 per mm^2, biseriate 15.62 per mm^2 and triseriate 25.15 per mm^2 (Table 11).

The sclereids are totally absent in the conducting zone, but they are present in the non-conducting zone. They form groups of varying magnitude. The sclereids are identified as brachy-type (Fig. 21B). The length of the sclereids ranges from 33 μm to 107.25 μm with an average of 73.60 μm, and the width varies from 33 μm to 66 μm with an average of 34.40 μm (Table 12). The sclereids occupy 13.57% of the non-conducting phloem and phelloderm in transection. (Table 13).

CASSIA SIAMEA LAM.

Macro-morphology

The bark is thick and appears light grey, nearly smooth, soft and scaly (Plate IIID). The lenticels are dark reddish brown and are clearly visible on bole surface. The distribution of lenticels per cm sq is about 2.5 lenticels. The rhytidome is thin and appears discontinuous because of lenticles. The lenticels are vertically placed without any order. The ray expansion tissue is fusiform and wide wedge-shaped (Fig. 5A).

The blazed bark is dark brown except the place of ray expansion tissues which appears pale yellow. Later it changes to greyish black and the ray expansion tissues into whitish yellow on exposure. The bark exfoliates is small irregular fragments of the average surface area of 30.3 x 17.1 mm^2 and thickness of 1mm.

Micro-morphology

The total bark thickness is 6 mm at the tree circumference of 80 cm. The rhytidome is about 0.7 mm thick and constitutes 11.66% of the entire bark, whereas the secondary phloem measures about 5.3 mm making 88.26% of the entire bark (Table 3).

The rhytidome comprises only one periderm around the entire circumference and the dead secondary phloem on the outer side of the periderm isolated by it. There are shallow fissures which are vertical and resulted by the splits in dead secondary phloem isolated by the periderm. Each periderm consists of phellogen, phellem and phelloderm. The phellogen is single layered with more or less rectangular cells as seen in transverse view. The phellem is a multi-layered zone of large thick-walled suberized cells, which are much flattened radially and arranged in compact radial rows. The phelloderm is many layered, the cells of which have non-suberized thin walls. They are squarish rectangular parenchymatous cells arranged in radial rows with intercellular spaces. The phelloderm cells are slightly larger than the phellem cells. A large number of sclereids in groups of varying magnitude are found dispersed among the phelloderm cells and a tangential band of sclereids is also found in the region of phelloderm (Fig. 13B).

The secondary phloem is differentiated into the conducting and non-conducting zones. The average depth of the conducting zone is 0.4 mm which constitutes 7.55% of the secondary phloem and 6.60% of the entire bark, whereas the depth of the non-conducting zone is found to

be 4.9 mm constituting 92.45% of the entire secondary bark and 81.66% of the total bark (Table 3 & 4).

The further detailed study of conducting zone reveals that the fibres mostly are in groups and their tangential extension constitute bands (Fig. 13B). However, the bands do not arrange themselves in distinct parallel tangential rows and the arrangement remains somewhat irregular (Fig. 13B). Between these two successive fibre bands are the sieve-tube elements, associated companion cells and axial parenchyma. The narrow abruptly ending rays pass radially almost straight in the conducting zone. The non-conducting phloem, on the other hand, persisted with obliterated or crushed sieve-tube elements and companion cells, sclereids and dilated rays.

The fibres are thick walled and lignified. They appear as the major component of secondary phloem forming successive irregular tangential bands at regular intervals (Fig. 13B). Each group is 1-2 cells wide in transectional view. The fibres occupy about 13.35% area of the conducting phloem in tranverse section (Table 5). In macerated bark samples, the fibre apices may be either smooth or tapering or may show diverse manifestation such as dentation, bifurcation and serration ends (Fig. 21C). The length of fibres ranges from 610.50 to 1551 µm with an

average of 995.36 µm, while the width varies from 16.50 to 33 µm with an average of 19.60 µm (Table 6).

The sieve-tube elements are characterized by compound sieve-plates situated on deeply inclined end walls (Plate IIIE). Lateral sieve areas are not much prominent on their lateral walls (Plate IIIE). The sieve-tube elements are arranged in a non-stratified pattern in tangential longitudinal view. The length of sieve-tube elements ranges from 198 µm to 528 µm with an average of 353.22 µm, whereas, the width from 16.50 µm to 41.25 µm with an average of 31.58 µm (Table 7). The sieve-tube elements are arranged in groups of 6-9 cells between the fibre bands and occupy 7.19% cross-sectional area of the conducting phloem (Plate IIIFand Table 5).

The axial parenchyma is comparatively much smaller in size than sieve-tube elements in cross-section, and form about 64.50% of the conducting phloem (Table 5). The cells are devoid of tannins both in the conducting and the non-conducting zones.

The rays are homogeneous in nature being composed of only procumbent cells. The rays are uniseriate to triseriate. They take almost straight radial run in the conducting phloem and adopt to deflection only in the non-

conducting phloem, a few rays resort to proliferation to obviously coup with the increasing circumference resulting in dilation of ray close to the periderm to produce ray expansion tissue (Fig. 13B). Alongwith the ray cells, axial parenchyma also divide to enhance the tangential area. Tannin is not detected in the ray cells of both the conducting and non-conducting phloem. The rays occupy about 14.96% area of the conducting phloem in transectional view (Table 5). The height of the rays is found to range from 4-16 cells with an average of 9.66 cells (198.72 μm), while the width from 1-3 cells with an average of 2.30 cells (36.48 μm) (Table 8). When the frequency of the rays with respect to height in conducting phloem is calculated, the short rays form 68% and medium 32% (Table 9). Likewise, the uniseriate rays form 3%, biseriate 82% and triseriate 5% (Table 10). On the other hand, the frequency of different types of ray per mm^2 in tangential longitudinal view in the conducting phloem, the uniseriate rays form 1.09, biseriate 30.93 and triseriate 11.24 per mm^2 (Table 11).

The sclereids are completely absent in the conducting phloem, but appear in the non-conducting phloem in the form of groups in addition to fibre groups. Brachy-type sclereids are identified (Fig. 21C). The length of sclereids

ranges from 66 μm to 240 μm with an average of 30.82 μm (Table 12). The area occupied by sclereids in the non-conducting phloem zones and phelloderm zones is about 13.18% (Table 13).

DELONIX **REGIA** RAF.

Macro-morphology

The bark is reddish brown, compact, soft nearly smooth and entire i.e.,without fissures (Plate VIIC). The rhytidome is thin and includes single superficial periderm. The ray expansion tissue appears wedge-shaped (Fig. 5B). The lenticels are clearly visible and are scattered on the entire bole surface. The average number of lenticels is estimated about 8.23 per cm^2.

When the stem bark is blazed, the outer bark is reddish brown and inner is whitish yellow. Later it becomes yellow brown on exposure. The bark flakes are oblong or irregular or thin rounded pieces of an average thickness of 1 mm and surface area measured to be about 11.84x5.73 mm^2.

Micro-morphology

The depth of bark is 4.4 mm in a tree trunk of 79cm circumference. The rhytidome is thin and measures about 1 mm and forms 22.72% of the total bark. Whereas the overall thickness of secondary phloem reaches about 3.4 mm constituting 77.28% of the total bark (Table 3).

The rhytidome consists of single superficial periderm. The periderms peel off along the stone cells in the phelloderm in the form of minute scales. The lenticels are composed of closing layers, and complementary cells which consist suberized and non-suberized cells. In transverse section the periderm has three usual constituents, i.e., the phellogen, phellem and phelloderm. The phellogen appears single layered, the cells of which are rectangular. The phellem constituents a narrow zone of 7 layers of suberized cells which are thick walled, very much flattened radially and arranged in compact radial rows. The phelloderm is multi-layered. It consists of rectangular parenchymatous cells with non-suberized walls, which have tannins and are arranged in radial rows leaving intercellular spaces among them. Sclereids are found in large groups or as isolated cells among the phelloderm cells and also in the non-conducting phloem zone (Fig.14A).

The secondary phloem is differentiated into the conducting and the non-conducting zones. The average depth of conducting zone measures 0.6 mm which forms 17.65% of the total secondary phloem and 13.64% of the entire bark. Whereas the depth of the non-conducting zone is found to be 2.8 mm constituting 82.35% of the secondary phloem and 63.64% of the total bark (Table 3 & 4).

The anatomical study of the conducting phloem reveals that the fibres are scattered either single or in groups of few cells (Fig. 14A). The sieve-tube elements occupy the position between the fibre groups with their associated companion cells, axial parenchyma, while the radially running wide rays maintain a straight path-way up to the conducting phloem region. The non-conducting phloem, on the other hand, differs in having collapsed or distorted sieve-tube elements and companion cells, sclereids and dilated and proliferated rays (Fig. 14A).

The fibres are thick-walled and lignified and the fibre groups do not have any arrangement (Fig. 14A). The fibre groups have 2-8 cells in transectional view. The fibres constitute about 7.06% of transectional area of the conducting phloem (Table 5). The study of individual fibres, from macerated materials has shown that they are occasionally with serrated, dentated and bifurcated apices (Fig. 21D). The length of the fibres ranges from 841.50 µm with an average of 1742.08 µm while their width varies from 16.50 to 33 µm with an average of 18.08 µm (Table 6).

The sieve-tube elements possess compound sieve plate on deeply inclined end wall (Plate VIII C). Lateral sieve

areas are also highly developed on the entire lateral walls (Plate VIIIC). The sieve-tube elements are arranged in a non-stratified order as seen in tangential longitudinal view. The length of sieve-tube elements varies from 250.50 µm to 726µm with an average of 445.28 µm, and the width from 33 to 52.80 µm with an average of 38.30 µm (Table 7). The sieve-tube elements are organised in tangential bands and occupy 54.63% area of the total conducting phloem in transectional view (Plate VIIID& Table 5).

The axial parenchyma is comparatively smaller than sieve-tube elements in transectional view. They occur mixed with the sieve-tube elements and companion cells in a randomized manner. They are also observed around the fibre groups. The axial parenchyma occupies about 18.72% transectional area of the conduting phloem (Table 5). Tannins are not occur in parenchyma cells in the entire secondary phloem.The rays are homogeneous as they are made up of only procumbent cells and are uniseriate, biseriate, triseriate and tetraseriate in tangential longitudinal section. The rays run more or less straight but take to a deflected pathway in the non-conducting phloem. Almost all the rays multiply and proliferate in the outer non-conducting phloem, i.e., near the periderm and give rise to the ray

expansion tissue (Fig. 14A). The ray cells are devoid of tannins in the conducting and the non-conducting phloem. The phloem rays form about 19.59% area of the conducting phloem in transectional view (Table 5). The ray height ranges from 4-50 cells with an average of 17.18 cells (343.20 μm), while the width ranges from 1-4 cells with an average of 2.92 cells (51.84 μm) (Table 8). The frequency of the rays with respect to their varying height in the conducting phloem reveals that short rays occupy 27.40%, medium 46.80% and tall 25.80% of the total ray population (Table 9). Similarly, uniseriate rays occupy 4%, biseriate 19%, triseriate 36% and tetraseriate 41% of total ray number (Table 10). The frequency of rays per mm^2 reveals that the uniseriate rays number 0.62, biseriate 2.96, triseriate 5.62 and tetraseriate 6.40 per mm^2 (Table 11). The secretory cells are observed as the biggest parenchymatous cells in the secondary phloem in groups of 1-2 cells (plate VIIID). The secretory cells do not have tannins in the conducting region, however they contain tannins in non-conductivity region.

The sclereids are completely lacking in the conducting phloem, however, they appear in the non-conducting zone, singly or in patches in addition to fibre fascicles (Fig. 14A). The sclereids are identified as brachy

type (Fig. 21D). The length of the sclereids ranges from 38 to 144 μm with an average of 90.75 μm, while the width ranges from 16.5 to 66 μm with an average of 36.64 μm (Table 12). The amount of sclereids is about 27.50% of the non-conducting phloem and phlloderm (Table 13).

ERYTHRINA INDICA LAM.

Macro-morphology:

The bark is thick,yellowish or greenish grey, shining, smooth (Plate IV A) with reduced number of thorns on the surface as complexed to young stem and peel off in thin papery flakes. Lenticels are clearly visible and are vertically scattered over the bole surface. The bark is cracked at places of lenticels. The number of lenticels per unit area is about 0.8 per cm^2. Rhytidome is thin with a superficial periderm. The ray expansion tissue is wide wedge shapedand runs a short distance (Fig. 5C).

When the bark is blazed, the blaze shows the outer portion green and the inner bark is yellowish, when fresh, which turns light brown after a few days exposure.

Micro-morphology:

The bark, in its entirely measures 10.5 mm in thickness, in the tree trunk having the circumference of 72 cm. The rhytidome is about 0.2 mm and forms 1.90% of the total thickness of bark, whereas, the over-all depth of secondary phloem is 10.3 mm which constitutes 98.10% of the entire bark (Table 3).

The rhytidome is constituted of single periderm, as periderm layers are continuously peeled off, in the form of thin and small fragments. The lenticels are composed of filling or complementary tissues with the limiting layers. The periderm is made up of phellogen, phellem and phelloderm. The phellogen appears to be single layered. The phellem is a broad zone of thick walled and suberized cells and the cells are somewhat flattened radially and arranged in compact radial rows. The phelloderm is multi-layered, the cells of which are non-suberized thin walled and possess crystal. These squarish and rectangular parenchymatous cells are arranged in radial rows without intercellular spaces. The phelloderm cells are more or less of the same size as that of cork cells. A very few sclereids occur amongst the phelloderm cells.

The secondary phloem is well differentiated into the conducting and non-conducting zones. The average depth of the conducting zone is 0.5 mm and constitute 4.85% of the entire secondary phloem and 4.77% of the total bark, whereas the depth of the non-conducting zone is found to be 9.8 mm constituting 95.15% of the secondary phloem and 93.33% of the total bark (Table 3 & 4).

The detailed study of the conducting phloem reveals that the fibres are either in small groups or isolated

cells, and they do not exhibit any orderly arrangements. Intermingled with the fibres are sieve-tube elements with their associated companion cells and axial parenchyma and the large wide rays running radially straight between these tissues in the conducting phloem. The non-conducting phloem, on the other hand, differs in having obliterated or crushed sieve-tube elements, and crushed or cleared companion cells sclereids and dilated rays, which run radially straight for a short distance before taking a wavy path in the outer portion of the zone.

The fibre is a mechanical component of the secondary phloem and it is found either isolated or in small groups (Fig. 14B). Each fibre groups is 3 to 6 cells wide in transectional view and constitute about 5.96% of cross-sectional area of the total conducting phloem (Table 5). In macerated material, the fibres apices appear either smooth and tapering or may show diverse manifestations such as forking and dentation (Fig. 22A). It is all normal. The length of fibres ranges from 610.50 µm to 1975 µm with an average of 1599.36 µm, whereas the width varies from 16.50 µm to 33 µm with an average of 18.24 µm (Table 6).

The sieve-tube elements are characterized by simple

sieve-plates, borne on slightly oblique end walls (Plate IVD). Sieve areas are prominent on lateral walls (Plate IVD). The arrangement of sieve-tube elements is stratified (Plate IVB). The length of sieve-tube elements ranges from 214.50 µm to 313.50 µm with an average of 245.28 µm while the width being 24.75 µm to 49.50 µm with an average of 34.56 µm (Table 7). The sieve elements occupy 27.49% transectional area of the conducting region (Table 5) & occur in groups 10-55 cells (Plate IVC).

The axial parenchyma cells are comparatively larger in size than sieve-tube elements in cross-sectional plane. They are mixed with the sieve-elements and fibre groups and form about 38.75% of transectional area of the conducting phloem (Table 5). The parenchyma cells do not contain tannins in the conducting as well as non-conducting zones.

The rays are homogeneous in nature as they are composed of only procumbent cells. The rays are multiseriate and majority of them are tall which disturb the stratified arrangement (Plate IVB). The transectional view reveals that the rays run almost straight into the conducting zone, only to take a deflected path-way in the non-conducting zone. All the ray cells multiply and prolife-

rate in the non-conducting phloem near the periderm and form ray expansion tissue (Fig. 14B). The ray cells are not found to contain tannins in the conducting as well as non-conducting zone. The phloem rays occupy about 27.80% of the cross-sectional area of the conducting phloem (Table 5). The ray height ranges from 10 to 120 cells with an average of 64.75 cells (2384.80 µm), whereas the width from 6 to 15 cells with an average of 12.10 cells (470.80 µm) (Table 8). The frequency of the rays with respect to height in the conducting zone, shows that the short rays are 14.20% and tall 85.80% of the total ray population (Table 9). Similarly, the universal rays are 6%, biseriate 6% and multiscriate 88% (Table 10). The frequency of different types of rays per mm^2 reveals that the uniscriate 0.10 per mm^2 biseriate 0.10 per mm^2 and multiscriate 1.36 per mm^2 (Table 11).

The sclereids are totally absent in the conducting phloem, but appear in the outer non-conducting region. They are found in the form of fascicles of varying magnitude as well as isolated elements. Sclereids are of brachy-type (Fig. 22A). The length of sclereids varies from 40 to 320 µm with an average of 98.08 µm, whereas the width from 24 to 64 µm with an average of 42.08 µm(Table 12).The area occupied by sclereids in the non-conducting and phelloderm zone is about 2.05% (Table 13).

ERYTHRINA SUBEROSA ROXB.

Macro-morphology:

The bark is creamy, corky, thick, rough, rugose with numerous irregular cracks and deep furrows (Plate VA). The fissures are numerous and irregular. The rhytidome is very thick because of thick cork of the single periderm. The ray expansion tissue is small wide and wedge shaped located at the base of cracks. The lenticels are not discernible on the surface.

The blazing of the bark exposes the pale-yellow outer bark, and reddish brown inner bark. Interestingly the colour does not change even on exposure. The bark is peeled off in the form of 63x36 mm^2 with an average thickness of 22.6 mm.

Micro-morphology:

The entire bark measures 22.6 mm in the trunk of 108 cm circumference of which the rhytidome accounts for about 16.3 mm and overall thickness of secondary phloem is about 6.3 mm which constitutes 72.12% and 27.88% of the total bark respectively (Table 3). The lenticels are not recognizable on the surface of the bole.

The thick rhytidome comprises only single periderm. The thickness of rhytidome is due to the wide zone of cork cells. The periderm runs around the entire circumference. The discontinuity of the bark is due to the cracks in the cork because of increasing bole circumference, resulting in the formation of fissures of various depth and size. The periderm consists of phellogen, phellem and phelloderm. The phellogen is single layered with more or less rectangular cells as seen in transectional view. The phellem is a wide zone of multi-layered cork cells with thick and suberized walls. There are narrow and wide cell layers forming zones. The cell of which are all flattened radially and arranged in compact radial rows. These zones alternate with another and give the impression of the presenece of growth layers. The phelloderm is also a multilayered zone, the cells of which have non-suberized walls. These squarish and rectangular parenchymatous cells are arranged in radial rows with prominent intercellular spaces The phelloderm cells are more or less of the size of the cork cells. A very few groups of sclereids are found in the non-conducting zone (Fig. 15A). The sloughing off of the bark takes place through the phellem. The lenticels are absent.

The secondary phloem is distinguished into the con-

ducting and non-conducting zones. The average depth of the conducting phloem measures to 1.2 mm and makes 19.05% of the secondary phloem and 5.31% of the total bark, while the depth of the non-conducting region is 5.1 mm which constitutes 80.95% of the secondary phloem and 22.57% of the total bark (Table 3 & 4).

The microscopic study of the conducting phloem reveals discontinuous tangential bands of fibres. Between two such bands are located the sieve-tube elements with their companion cells and axial parenchyma, while large wide rays run radially almost straight into the non-conducting phloem. The non-conducting phloem, on the other hand, possesses obliterated or collapsed sieve-tubes and companion cells, sclereids and dilated rays, which run radially straight for a short distance before taking a wavy path in the outer region.

The fibres are thick-walled and lignified. They are arranged in discontinuous tangential bands (Fig. 15A). Each fibre band is 1-6 cells wide in transectional view. The fibres contitute about 8.45% of the cross-sectional area of the conducting phloem (Table 5). The fibre apices may be either smooth and tapering or may show diverse mani-

festations such as dentation (Fig. 22B). The length of fibres ranges from 627 µm to 1897.50 µm with an average of 1281.28 µm, while the width from 24.75 µm to 33 µm with an average of 31.20 µm (Table 6).

The sieve-tube elements are characterized by simple sieve plate borne on short and slightly oblique end walls (Plate V B). They also possess conspicuous lateral sieve-areas on their lateral walls (Plate VB). Sieve-tube elements are arranged in a stratified order as seen in tangential longitudinal plane (Plate VC). The length of sieve-tube elements ranges from 181.50 µm to 577.50 µm with an average of 353.16 µm, whereas the width ranges from 18.15 µm to 41.25 µm with an average of 36.19 µm (Table 7). The sieve-tube elements occur in groups of 12-60 cells between the fibres fascicles and occupy about 20.37% area in transectional view (Plate VD & Table 5).

The axial parenchyma is comparatively smaller than the sieve-tube elements in transectional view. They occur with the sieve-tube elements and companion cells in a randomized manner. They are also observed around the fibre groups. The axial parenchyma occupies about 37.85% transectional area of the conducting phloem(Table 5). Tannins

are absent in the parenchyma of the conducting and the non-conducting phloem.

The rays are homogeneous in nature as they are composed of only procumbent cells. They look invariably multiseriate in tangential longitudinal view. They run almost straight throughout the conducting zone but all the rays take deflected path in the outer non-conducting zone. Obviously, the ray cells multiply and proliferate in the non-conducting phloem up to the periderm, to give rise to the ray expansion tissue and causes their deflection (Fig. 15A). The ray cells are not found to contain tannin both in the conducting and non-conducting zones. The phloem rays occupy about 33.33% area of the conducting phloem in transectional view (Table 5). The height of the rays ranges from 22-71 cells with an average of 47.40 cells (1350.40 µm), whereas the width ranges from 8-12 cells with an average 10.20 cells (297.60 µm) (Table 8). Analysis of the frequency of the rays of different height in the conducting phloem shows that short rays are 26% and tall rays are 74% of the total ray population (Table 9). Similarly, the uniseriate 3%, biseriate 3%, triseriate 7% and multiseriate 87% of total number of rays are observed in tangential longitudinal plane (Table 10). The frequency

of uniseriate rays is 0.16 per mm^2, biseriate 0.16 per mm^2, triseriate 0.42 per mm^2 and multiseriate 1.67 mm^2 of total ray population (Table 11).

The sclereids are not observed in the conducting phloem. They occur only in the outer non-conducting zone (Fig. 15A). These sclereids are like brachy-type (Fig.22B). The length of sclereids rnages from 66-313.50 µm with an average of 183.65 µm, whereas the width varies from 33-99µm with an average of 61.38 µm(Table 12). Area occupied by sclereids in the non-conducting is about 3.04% (Table 13).

GLIRICIDIA MACULATA JACQ.

Macro-morphology:

The bark is pale-green or greyish green, soft and smooth (Plate VIA). The rhytidome is thin and includes only one superficial thin periderm. The ray expansion tissue is fusiform and small narrow wedge shaped (Fig.6B). The lenticeles are not traceable on the surface.

When the bark is blazed, the outer bark is green and inner is yellowish. The exfoliation occurs in the form of minute thin irregular scales with an average thickness of 0.77 mm and surface area of 3.8 x 2.7 mm^2 and even as powder.

Micro-morphology:

The total bark thickness is of the measure of 7.0 mm in a tree trunk of 67 cm circumference. The rhytidome is about 1.4 mm which forms 20% of the total bark, whereas the over-all thickness of secondary phloem comes to about 5.6 mm constituting 80% of the total bark (Table 3).

The rhytidome is thin and composed of only one periderm which runs around the entire circumference. The peri-

derm peels off along stone cells in the form of irregular scales of various sizes and which consists of only secondary phloem cells shapes. The lenticels are not observed. The periderm has the usual three main component regions i.e. phellogen, phellem and the phelloderm. The phellogen appears single layered with rectangular cells which are filled with tannins. The phellem is a multilayered zone. The phellem cells are thick walled, suberized, flattened radially and arranged in compact radial files. The phelloderm is also a multilayered zone, the cells of which have thin non-suberized walls. These rectangular parenchymatous cells are arranged in radial rows without intercellular spaces and the cells are more or less of the same size as that of phellem cells.

The secondary phloem is differentiated into the conducting and non-conducting zones. The average depth of the conducting phloem is 1.7 mm which forms 30.36% of the total secondary phloem and 24.28% of the total bark, whereas the depth of the non-conducting zone is measured as 3.9 mm constituting 69.64% of the secondary phloem and 55.72% of the total bark (Table 3 & 4).

The microscopic examination of the conducting phloem reveals that the fibres are grouped in irregular tangential

bands. Between these bands the area is occupied by the sieve-tube elements with their associated companion cells, axial parenchyma and rays which are fine and running radially, keeping a straight pathway in the conducting region (Fig. 15B). The non-conducting phloem, on the other hand is recognized by collapsed or distorted sieve-tube elements and companion cells, sclereids and dilated rays, which adopt a wavy path in the entire non-conducting phloem zone.

The fibres, the most important constituent of secondary phloem, are grouped in discontinuous tangential bands (Fig. 15B). Each band is 2-5 cells wide in transectional view, and constitute about 10.09% of the transectional area of the conducting phloem (Table 5). The fibres apices either smooth and tapering or may show diverse appear manifestations such as forking, serration and dentation (Fig.22C). It is all normal. The length of fibres ranges from 33 µm to 1204.50 µm with an average of 770.56 µm, whereas the width varies from 16.50 µm to 41.25 µm with an average of 22.08 µm (Table 6).

The sieve-tube elements are fashioned by simple sieve plates, situated on slightly oblique end walls (Plate VIC). The lateral sieve areas are not conspicuous on the lateral walls of sieve elements. The arrangement

of sieve elements is stratified (Plate VID). The length of sieve-tube elements varies from 165 µm to 213.50 µm with an average of 189.76 µm, whereas the width from 16.50 µm to 33 µm with an average of 21.60 µm(Table 7). The sieve elements are found in groups of 4-13 cells, and occupy 15.98% area of the conducting phloem in transectional plane (Table 5).

The axial parenchyma cells are rather smaller than the sieve-tubes in cross-sectional view. They occur around the groups of sieve-tube elements and the companion cells and contain druses/tannins in the conducting as well as the non-conducting zones.

The rays are homogeneous in nature as they are made up of only procumbent cells. The rays are uniseriate to tetraseriate. The cross-sectional view reveals that the rays run straight in the conducting phloem zone and take a deflected path as they enter in the non-conducting zone (Fig. 15B). Few rays multiply and proliferate up to the outer extreme of the non-conducting phloem zone, to give rise to the ray expansion tissue (Fig. 15B). The ray cells do not contain tannins or druses both in the conducting and the non-conducting zones. The phloem rays occupy about 20.35% area of the conducting phloem in transec-

tional view (Table 5). Rays are arranged in a stratified manner as seen in tangential longitudinal view (Plate VI D). The height of rays varies from 3-8 cells with an average of 6.32 cells (147.20 µm), whereas the width from 1-4 cells with an average of 2.04 cells (38.40 µm) (Table 8). Analysis of the height of rays in the conducting phloem reveals that there are only short rays in total ray population as seen in tangential longitudinal plane (Table 9). As regards the frequency of occurrence of rays of different seriations the uniseriate rays are 18%, biseriate 48%, triseriate 31% and tetraseriate 3% of total number of rays (Table 10). As to the frequency of different types of rays per mm^2 is concerned the uniseriate rays number 12.88, biseriate 33.59 triseriate 21.98 and tetraseriate 3.12 per mm^2 (Table II).

The sclereids are entirely absent in the conducting phloem although occur in small groups of various sizes in the outer non-conducting phloem in addition to fibre groups (Fig. 15). Sclereids are of brachy-type (Fig. 22C). The length of the sclereids is found to range from 33 µm to 99 µm with an average of 51.52 µm, whereas the width from 33 µm to 82.50 µm with an average of 46.88 µm (Table 12). Amount of sclereids in the non-conducting zone is observed to be about 8.2% (Table 13).

HARDWICKIA BINATA ROXB.

Macro-morphology:

The bark appears darkgrey and rough is shallow fissured(Plate VIIA).Fissures are both vertical and horizontal. Under hand lens, these fissures are irregular. The rhytidome is thick and has many periderm layers, which is discontinuous and spreads tangentially to short distance and then deviate out wardly (Fig. 7A). The ray expansion tissue is observed. They are long but narrow wedge shaped and look irregular (Fig. 7A). The lenticels are clearly visible and mostly situated horizontally on the surface of bole. They appear blackish brown and the number of lenticels per cm^2 is calculated to about 4.78.

When the bark is blazed, it exposes reddish brown outer and pale-yellow inner and the colour turn dark brown on exposure. The bark peels off more or less in the form of squarish papery flakes with an average thickness of 1.5 mm and size of 10.8 x 10.2 mm^2.

Micro-morphology:

The bark is 12 mm in depth in a tree trunk of the circumference of 64 cm. The rhytidome is about 3.4 mm in thickness and forms 28.33% of the total bark, whereas the

overall secondary phloem measures to about 8.6 mm and constitutes 71.66% of the total bark (Table 3).

The rhytidome is composed of several discontinuous periderms, leaving only one periderm around the entire circumference at a time. This discontinuity of the outer periderms is obviously caused by the pressure exerted by increasing bole circumference, and the broken periderms tend to stick for years on the trunk resulting in the formation of fissures of various sizes and depths. The periderm consists of usual phellogen, phellem and phelloderm zones. The phellogen is single layered with almost rectangular cells as seen in transectional view. The phellem forms large zone of thick walled suberized cells which are arranged in compact radial rows. The phelloderm is 2-3 layered, the cells of which are non-suberized, squarish and parenchymatous but without inter-cellular spaces. They are arranged in radial rows. Mostly the phelloderm cells contain tannins and are more or less similar to the cork cells. The sloughing off of the bark takes place by the breakdown of phellem cells in the form of thin and small irregular pieces. The lenticles are observed on the surface of the trunk.

The secondary phloem is well differentiated into the conducting and non-conducting zones. The average depth of

the conducting zone is 0.8 mm and that of the non-conducting zone is 7.8 mm constituting 9.30% and 90.7% of the secondary phloem respectively and 6.66% and 65% of the total bark respectively (Table 3 & 4).

As regards the other details of the conducting phloem the fibres are the main constitutents. They are thick-walled, well lignified and arranged in groups which tend to form discontinuous, tangential bands (Fig. 16A). Between the two successive bands of fibre fascicles are the sieve-tube elements with their associated companion cells, and axial parenchyma. The rays are fine and running radially between fibre fascicles straight through the conducting zone (Fig. 16A). The non-conducting phloem is recognized by the obliterated or crushed sieve-tube elements and companion cells and the collapsed rays in the outer region.

The fibre fascicles are 2-5 cells wide tangentially, in cross-sections, constituting about 10.34% of the conducting phloem (Table 5). Structurally the fibre apices may be either smooth and tapering or may show diverse manifestations such as septate and dentate (Fig. 22D). The length of fibres ranges from 544.50 µm to 2343 µm with an average of 1548.64 µm, whereas the width varies from 8.25 µm to 16.50 µm with an average of 12.22 µm (Table 6).

The sieve-tube elements are provided with simple sieve plates, borne on short and slightly oblique end walls (Plate VIIB). They also possess lateral sieve areas on their lateral walls (Plate VIIB). Sieve elements are arranged in non-stratified order. The length of sieve-tube elements is found to range from 198 µm to 333 µm with an average of 252.16 µm, while the width varies from 24.75 µm to 33 µm with an average of 28.32 µm (Table 7). The sieve elements form distinct groups of 2-5 cells and occupy 6.01 % cross-sectional area of the conducting phloem (Plate VIID Table 5).

The axial parenchyma cells are of the size of the sieve elements in transectional view. They occur with sieve elements and companion cells (Plate VIID), and form about 65.74 %transectional area of the conducting phloem (Table 5). The parenchyma cells are found to contain tannins in the conducting region, and are enriched with tanniferous substances in the non-conducting region.

The rays are homogeneous in nature and exclusively made of procumbent cells and are uniseriate to triseriate. They run almost straight through the conducting zone to the non-conducting zone, where-upon they mostly get collapsed. At the same time some of the rays multiply in the non-conducting phloem giving rise to large but narrow wedge -

shaped ray expansion tissue. The ray cells are enriched with tanniferous substances both in the conducting and non-conducting regions. The phloem rays occupy about 17.91% area of the conducting phloem in tran-sectional plane (Table 5). The height of the rays ranges from 4-16 cell with an average of 8.63 cells (246.72 µm), whereas the width from 1-3 cells with an average of 1.73 cells (27.36 µm) (Table 8). The analysis of the frequency of the rays of different height in the conducting phloem shows that short rays form 63.30%, medium 36.70% and tall ones are completely lacking in the population (Table 9). And the uniseriate rays are 43%, biseriate 49% and triseriate 8% of the total number of rays (Table 10). On the other hand the frequency of different types of rays per mm^2 reveals that the uniseriate rays number 21.70, biseriate 24.52 and triseriate 3.90 per mm^2 (Table 11).

The sclereids are not observed in the conducting phloem. They are found only in phelloderm. They are isolated or in groups of 2-5 sclereids in transectional view. The area occupied by selereids is to about 2.08% (Table 13). The brachy-type selereids are observed (Fig. 22D). The length of sclereids varies from 49.50 µm to 82.50 µm with an average of 61.88 µm, while their width varies from 33 µm to 72.25 µm with an average of 46.69 µm (Table 12).

PARKIA ROXBURGHII G. DON

Macro-morphology:

The bark is grey, soft, shallow fissured and with brownish vertical lenticels closely spaced and scattered over the entire surface (Plate VIIIA).The distribution of the lenticels is about 0.8 per sq cm. The rhytidome is thin and includes single superficial periderm that runs parallel to the cambium. The ray expansion tissue is observed as large but wide wedges commencing from the outer part of the non-conducting region of the secondary phloem up to the periderm (Fig. 7B).

When the bark is blazed, it exudes reddish juice. The blaze exposes the brick red colour which gradually becomes reddish brown on exposure. The exfoliation of the bark occurs in the form of small thin irregular pieces with an average thickness of 2.33 mm and the size of these averaged to be about 12.25x8.38 mm^2.

Micro-morphology:

The total thickness of the bark is 12.9 mm in a tree trunk having a circumference of 108 cm. The rhytidome measures about 2.3 mm in depth and forms 17.83% of the total bark, whereas the overall thickness of the secondary

phloem is about 10.6 mm which constitutes 82.17% of the total bark (Table 3).

The rhytidome is composed of a single superficial periderm which encircles the entire girth. The structural components of the periderm are the usual phellogen, phellem and the phelloderm. The phellogen is single layered, with rectangular cells. The phellem forms a broad zone of thick walled suberized as well as thin walled non-suberized cells. The former are flattened radially while the later are extended radially but the over-all arrangement is compact and in radial rows. The phelloderm is multi layered, the cells of which possess non-suberized wall. These squarish and rectangular parenchyma cells are with intercellular spaces and not strictly arranged in radial rows. The phelloderm cells are more or less of the size of cork cells. The lenticels are composed of two types of cells, constituting the complementary tissue and the closing layer.The lenticels are situated close to the outer ends of the ray expansion tissue of the phloem. A number of sclereids, forming groups are dispersed among the phelloderm cells of which large groups are in old exterior secondary phloem zone. A tangential band of sclereids is also occurred in between the secondary phloem and phelloderm (Fig. 16B).

The secondary phloem is easily distinguishable into the conducting and non-conducting zones. The average depth of the conducting zone is found to be 2.4 mm which forms 22.64% of the secondary phloem and 18.60% of the total bark. The depth of the non-conducting zone measures 8.2 mm constituting 77.36% of the secondary phloem and 63.57% of the total bark (Table 3 & 4).

Minute anatomical study of the conducting phloem reveals that the fibres are arranged in groups which tend to coalesce to form tangential bands. Between such bands of fibre fascicles, the sieve-tube elements are situated with their associated companion cells and axial parenchyma. The rays take a straight radial path in the conducting phloem. On the contrary, the non-conducting phloem, consists of obliterated or crushed sieve-tube elements, crushed or cleared companion cells, sclereids and dilated and deflected rays (Fig. 16B).

The fibres are thick walled and lignified. They represent the major components of the secondary phloem and are grouped in tangential bands occurring at irregular intervals (Fig. 16B). Each fibre band is 3-5 cells wide in cross-sectional view. The fibres constitute of cross-sectional area about 10.04% of the conducting phloem (Table 5).

In macerated sample, the fibre apices may be either smooth and tapering or may show diverse manifestation such as serrate and dentate (Fig. 23A). It is all normal. The length of fibres varies from 429 µm to 1930.50 µm with an average of 1111.20 µm, whereas the width measures from 8.25 µm to 16.50 µm with an average of 14.56 µm (Table 6).

The sieve-tube elements are provided with compound sieve-plates, borne on deeply inclined end walls (Plate VIIIE). Sieve areas are also conspicuous on the lateral walls (Plate VIIIE). The sieve-tubes are arranged in a non-stratified manner. The length of sieve-tube elements ranges from 156.75 to 561 µm with an average of 327.52 µm, while the width is 16.50 to 33 µm with an average of 34.05 µm (Table 7). The sieve elements are surrounded by parenchyma cells and are arranged in distinct groups of 5-12 cells, and occupy 10.62% area of the conducting region in transectional view (Plate VIIIBand Table 5).

The axial parenchyma cells are comparatively smaller in size than the sieve-tube elements in cross-section and form about 54.42% of the transectional area of the conducting phloem (Table 5). They contain tannins in the non-conducting phloem.

The rays are homogeneous in nature as they are

composed of only procumbent cells. The rays are uni to triseriate. They get mostly deflected as they enter the non-conducting zone. The deflection is marked and is due to the pressure caused by the multiplication and proliferation of ray cells in the non-conducting phloem, which gives rise to the ray expansion tissue (Fig. 16B). The ray cells are devoid of tannins in the conducting as well as non-conducting phloem zones. The phloem rays occupy about 24.92% area of the conducting phloem in transectional plane (Table 5). The ray height ranges from 3 to 30 cells with an average of 16.29 cells (288.96 μm), whereas the width from 1 to 5 cells with an average of 2.75 cells (51.04 μm) (Table 8). As regards the frequency of the rays with varying heights in the conducting zone, the short rays form 28.60%, medium 46.40% and tall 25% of the total ray population (Table 9). Similarly, the uniseriate rays form 26%, biseriate 33%, triseriate 16%, tetraseriate 22%, multiseriate 3% of the number of rays (Table 10). As to the frequency of different types of rays per mm^2 the uniseriate rays number 7.67, biseriate 9.83 triseriate 4.84, tetraseriate 6.40 and multiseriate 0.77 per mm^2 (Table 11).

The sclereids are totally lacking in the conducting phloem. They appear in the non-conducting phloem region in addition to fibre bands but independently. They form fasc-

icles of varying magnitude and also occur as isolated elements (Fig. 16B). They are recognised as brachy-type (Fig. 23). The length of sclereids ranges from 32 to 160 µm with an average of 63.20 µm, whereas the width varies from 24 to 56 µm with an average of 37.76 µm (Table 12). The area occupied by sclereids in the non-conducting phloem and phelloderm zone is about 4.12% (Table 13).

PELTOPHORUM PTEROCARPUM (DC) BACKER EXK. HEYNE.

Macro-morphology:

The bark appears as dark grey to greyish brown and sometimes partly blackish. It is hard, rough and shallow fissured (Plate IXA). The fissures are v-shaped. The bark peels off in the form of scales. The lenticels are both horizontally and vertically scattered on the surface. The frequency of lenticels per unit area is found to be about 2.2 lenticels per cm^2. The rhytidome is thick and includes a number of periderm layers that run parallel to the cambium for some distance and then deviate outwards. The ray expansion tissue is narrow wedge-shaped (Fig.7C).

When the bark is blazed, the blaze exposes soft creamy surface which remains unchanged on exposure for a few days. The bark sheds off in the form of long wide vertical strips of the average size of 64 x 32 mm^2 and thickness 2.5 mm.

Micro-morphology:

As a whole, the thickness of the bark is 8.5 mm in a tree trunk of 152 cm circumference. The rhytidome measures about 2.5 mm in thickness and forms 29.4% of the total bark, whereas, the overall thickness of the secondary

phloem is about 6.0 mm which constitute 70.58% of the total bark (Table 3).

The thick rhytidome comprises several discontinuous periderms leaving only one periderm around the entire circumference at a time. This discontinuity of the outer periderms is apparently caused by the pressure exerted by increasing bole circumference, which ultimately leads to the formation of fissures of various depths and sizes. The structural components of each periderm are the well defined, phellogen, phellem and phelloderm. In transectional view, the phellogen is single layered with rectangular cells. The phellem forms a broad zone of thick-walled suberized cells which are somewhat flattened radially and arranged in compact radial rows. The phelloderm is multi-layered. The cells of phelloderm are not easily visible in the transverse section due to highly tannin and other organic materials in them. Therefore, the layers of phelloderm, and shape and size of its component cells is obscured. The phelloderm cells are more or less of the same size as that of cork cells. A large number of sclereids forming groups are dispersed among the phelloderm cells which are more marked in older portion of the secondary phloem (Fig. 17A).

The secondary phloem is differentiated into the conducting and the non-conducting zones. The average depth of the conducting zone is found to be 1.0 mm which constitutes 16.67% of the total secondary phloem and 11.76% of the total bark, whereas, the depth of the non-conducting zone comes to 5.0 mm constituting 83.33% of the secondary phloem and 58.82% of the total bark (Table 3 & 4).

The study of the conducting phloem further reveals that the fibres are arranged in groups which tend to coalesce to form tangential bands (Fig. 17A). Between such bands of fibre fascicles, the sieve-tube elements are situated with their associated companion cells and axial parenchyma, and the fine rays running between them radially straight in the conducting phloem. While the non-conducting phloem, is identified on the basis of collapsed cells which demark it from the conducting phloem zone. The crushed sieve-tubes, parenchyma and wavy rays distinguish the non-conducting zone. The rays collapse in the outer region of the non-conducting phloem.

The fibres are thick walled and lignified. They represent the only mechanical component of the tissue secondary phloem and are grouped in irregular tangential bands occurring at irregular intervals (Fig. 17A). Each fibre group is 2 to 3 cells wide in transectional plane.

The fibres constitute about 14.23% area of the total conducting phloem in cross section (Table 5). The length of fibres ranges from 346.50 µm to 1468.50 µm with an average of 851.20 µm, whereas, the width falls in the range of 13.20 µm to 24.75 µm with an average of 16.32 µm (Table 6). The fibres apices are largely smooth and tapering but bifurcated ends and septate are also occasionally found (Fig. 23B).

The sieve-tube elements are provided with compound sieve plates and the end walls are deeply inclined (Plate IXB). Lateral sieve areas are also conspicuous on the lateral walls (Plate IXB). The arrangement of sieve-tubes is non-stratified. In cross section they are found in small groups of 2-5 cells and occupy about 8.36% area of the total conducting phloem (Plate IXD & Table 5). The length of sieve-tube elements is found to range from 156.75 to 577.50 µm with an average of 351.36 µm, whereas the width is from 16.50 µm to 36.30 µm with an average of 27.78 µm (Table 7).

The axial parenchyma cells are comparatively smaller in size than the sieve-tube elements in cross-sections(Plate IXD). They occur around the groups of sieve-tube elements and the associated companion cells and form about 61.05% of cross

sectional area of the conducting phloem (Table 5). The parenchyma cells are found to contain tannins both in the conducting and the non-conducting zones.

The rays are homogeneous in nature as they are composed of only procumbent cells. The rays mostly appear narrow in corss sections, and are both uni and biseriate. They get mostly deflected as they enter the non-conducting zone which is quite marked. The ray cells do not multiply even in the non-conducting phloem, therefore, the ray expansion tissue is absent, and the deflection is due to the divisions in the parenchymatous cells of the adjoining region. The ray cells are devoid of tannins in the conducting as well as the non-conducting phloem. The ray height ranges from 4 to 8 cells with an average of 10.76 cells (182.88 µm), whereas their width ranges from 1 to 2 cells with an average of 1.18 cells (18.90 µm) (Table 8). As regards, the frequency of the rays with respect to height in the conducting zone, the short rays form 48.60% and medium 51.40% (Table 9). Similarly, the percentage of the uniseriate rays is 89% and that of the biseriate is 11% (Table 10). The frequency of different types of rays per mm^2 reveals that the uniseriate rays number 49.37 and biseriate 6.40% per mm^2 (Table 11).

The sclereids are totally lacking in the conducting phloem, and appear in the non-conducting region in addition to fibre groups but independently. They are found in the form of fascicles of varying magnitude and are quite prominent (Fig. 17A). Sclereids are recognised as brachy-type (Fig. 23B). The length of the sclereids varies from 80.50 to 330 µm with an average of 170.24 µm, whereas the width from 24.78 to 80.25 µm with an average of 42.24 µm (Table 12). The area occupied by sclereids in the non-conducting zone is about 26.38% (Table 13).

PROSOPIS JULIFLORA DC.

Macro-morphology:

The bark is greyish brown, rough, hard and longitudinally deep fissured (Plate IXC). The rhytidome is thick and includes number of periderms which run more or less parallel to each other (Fig.8A). The ray expansion tissues and lenticels are absent (Fig. 8A).

When the bark is blazed, it shows the inner bark light yellow or creamy in colour, later changesinto yellowish brown; and outer is dark brown which remains unchangedon exposure. The exfoliation of dead bark is in the form of flakes with an average thickness of 2.4 mm and surface area of 92 x 11 mm^2.

Micro-morphology:

The total bark thickness is 9.2 mm in a tree with a circumference of 72 cm. The rhytidome is about 4 mm thick, whereas the secondary phloem measures about 5.2 mm making 43.48% and 56.52% of the entire bark respectively (Table 3).

The rhytidome comprises several narrow layers of periderm and wide layers of dead secondary phloem. Multi inner well developed periderm layers remain intact around the entire circumference (Fig. 17B). The discontinuity of the outer periderms are caused by the pressure exerted by increasing bole circumference, resulting in the formation of fissures of various depth and sizes. Each periderm consists of phellogen, phellem and phelloderm. The phellogen is single layered with more or less rectangular cells as seen in transectional view. The phe-

llem is 1 or 2 layered. The phellem cells are thick walled and suberized and not much flattened radially but arranged in compact radial rows. The phelloderm is 1 or 3 layered in transectional view, the cells of which have thin non-suberized walls. These squarish or rectangular peranchymatous cells are arranged in radial rows without intercellular spaces. Between the two successive periderms, the depth of non-functional secondary phloem varies from 844.19 um to 960.47 um with an average of 913.96 um. All of the periderm layers run more or less parallel to each other (Fig. 17B). Sclereids are very few and are dispersed. The bark is sloughed with large size of dead secondary phloem through the breakdown of phellem cells.

The secondary phloem is distinguished into the conducting and the non-conducting zones. The average thickness of the conducting zone is 0.7mm which forms 13.46% of the secondary phloem and 7.61% of the total bark, while the non-conducting zone is measured 5.2 mm constituting 86.54% of the secondary phloem and 48.91% of the total bark (Table 3 & 4).

The microscopy of the conducting zone shows that the fibres are mostly grouped in tangentially extended bands. The successive bands are almost at regular intervals. Between two successive bands are observed the sieve-tube elements, associated companion cells and axial parenchyma, while the narrow and few broad radial rays pass almost straight throughout the conducting zone to enter the non-

conducting zone, making way more or less between two closely related fibre bands. The rays are dilated in the outer non-conducting phloem. Few rays in the outer non-conducting phloem undergo proliferation and form expansion tissue and such rays are known as expansion rays. The non - conducting zone, distinctly possesses obliterated sieve-tube elements and companion cells, and the dilated rays.

The fibres are thick-walled and lignified. They occur in successive tangential bands (Fig. 17B). Each fibre band is 2 - 5 cells broad in transectional view. The fibres occupy 12.30% transectional area of the conducting zone (Table 5). The individual fibres are occasionally with septate and forked ends (Fig. 23C). The length of fibre elements is found to range from 528 to 1369.50 µm with an average of 976.64 µm, while the width from 16.50 to 24.75 µm with an average of 20.63 µm (Table 6).

The sieve-tube elements posses compound sieve plates on deeply angled end walls (Plate IXE). They are arranged in a non-stratified order. The lateral sieve areas

are well defined on the lateral walls (Plate IXE). The sieve tubes occur in groups of 2-19 cells occupying the spaces between the two fibre bands (Plate IXF). The transectional area occupied by the sieve-tube elements in the conducting zone is about 26.78% (Table 5). The length of the sieve-tube elements ranges from 148.50 to 330 µm with an average of 224.64 µm, whereas the width varies from 16.50 to 29.70 µm with an average of 19.23 µm (Table 7).

The axial parenchyma cells are smaller in size than sieve-tube elements in transectional view. They occur below the fibres band in 2 or 3 cells layer and above the fibre bands (Plate IXF). In addition to this, parenchyma are mixed with the sieve-tube groups. The transectional area occupied by axial parenchyma in the conducting zone is calculated to about 46.44% (Table 5).

The rays are homogeneous as they comprise only procumbent cells. The rays look uniseriate to multiseriate in tangential longitudinal view. They run almost straight through the conducting region to the non-conducting region, but deflect as they near the periderm. Only at the base of periderm proliferation is noticed in few rays. The ray cells, devoid of tannins in the conducting zone, are enriched with tanniferous substance in the non-conducting zone. The phloem rays constitute about 14.48% of the total

area of the conducting phloem (Table 5). The height of the rays is found to range from 6-37 cells with an average of 16.65 cells (230.08 µm), the width ranges from 2-5 cells with an average of 3.22 cells (34.56 µm) (Table 5). Analysis of the frequency of the rays of different height in the conducting phloem shows that short rays occupy 22.90%, medium 52.10% and tall 25% of the total ray population (Table 9). Similarly, uniseriate rays form 17%, biseriate, 29% triseriate 31% and tetraseriate 23% of the total ray number (Table 10). On the other hand, frequency of different types of rays per mm^2 reveals that the uniseriate rays number 5.31 per mm^2, biseriate 8.90 per mm^2, triseriate 9.68 per mm^2 and tetraseriate 7.03 per mm^2 (Table 11).

The sclereids are entirely lacking in the conducting phloem, although they occur in small groups in addition to fibre bands in the region of the rhytidome (Fig. 17B). The sclereids are of brachy type (Fig. 23C). The length of the sclereids ranges from 24.75 µm to 66 µm with an average of 50.18 µm, whereas the width varies from 16.50µm to 49.50µm with an average of 33.47 µm (Table 12). Area occupied by sclereids in the non-conducting zone is found to be 5.56% (Table 13).

PTEROCARPUS MARSUPIUM ROXB.

Macro-morphology:

The bark appears whitish grey or light brown, rough, heavy and deeply fissured. Fissures are placed both horizontally and vertically (Plate XA). The rhytidome is thick and includes many overlapping periderm layers which however, cover only short distances tangentially. The ray expansion tissue is of two types, large narrow and small wide wedge-shaped (Fig. 8B). The lenticels are not seen due to deep fissures.

When the bark is cut, a red juice exudes which hardens into a red astringent gum. The gum ducts are clearly visible even without the help of a lens. The inner bark is pale-yellow in colour while the outer bark is blackish brown. On exposure bark changes to balckish brown, or greyish brown colour. The shedding of the bark occurs in irregular flakes with an average thickness of 4.15 mm and surface area about 50.3 x 23.3 mm^2.

Micro-morphology:

The depth of bark is 13 mm in a tree trunk of 102 cm circumference. The rhytidome measures to about 6.8 mm in thickness and constitutes 52.16% of the total bark, whereas

the secondary phloem is about 6.2 mm and constitutes 47.84% of the total bark (Table 3).

The rhytidome is made up of multiple periderms. There are number of periderms running around the entire circumference without any crack (Fig. 18A). The space between two successive periderms varies from 0.91 mm to 1.27mm. The outer periderms break at several places due to the perssure exerted by increasing trunk circumference. These discontinuous periderms fruther break before they slough off as small irregular pieces through the phellem. Each periderm consists of phellogen, phellem and phelloderm. The phellogen is single-layered with rectangular cells in transectional view. The phellem is a 1-2 layered zone of thin walled, non-suberized cells, which were not flattened radially though arranged in compact radial rows. The phelloderm is 2-3 layered, the cells of which have thin and non-suberized walls. These squarish and rectangular parenchymatous cells are arranged in radial rows and are without intercellular spaces. The phelloderm cells are almost of the same size as that of cork cells. The lenticels are not discernible.

The secondary phloem is differentiated into conducting and non-conducting zones. The average depth of the

conducting phloem is 0.7 mm which constitutes 11.25% of the total secondary phloem and 5.38% of the total bark, whereas the depth of the non-conducting zone is calculated as 5.5 mm making 88.75% of the entire secondary phloem and 42.46% of the total bark (Table 3 & 4).

The detailed study of conducting phloem reveals that fibres are present either in groups or in isolation. They are mostly in discontinuous tangential bands. Between two such bands of fibre fascieles the sieve elements are located with companion cells, axial parenchyma and secretory cells. The radially running fine rays pass almost straight reaching the outer zone of the non-conducting phloem, making way between the fibre fascicles. The non-conducting phloem, on the other hand, is identified on the basis of obliterated or crushed sieve-tube elements and companion cells. All rays do not proliferate and it is limited producing narrow wedge-shaped expansion tissue. And the rays maintain a straight path.

The fibres are well lignified and their number does not further increase in the non-conducting zone as no new cell differentiation takes place (Fig. 18A). They occur as the major component of the secondary phloem and are arranged in tangential bands but are far from being conti-

nuous (Fig. 18A). Each fibre group is 2-5 cells wide in transectional view. The fibres constitute about 10.94% of cross-sectional area of the conducting phloem (Table 5). The fibres are normal at times with serrated and flattened apices (Fig. 23D). The length of fibres varies from 907.50 µm to 1732.50 µm with an average of 1236.81 µm, whereas, the width varies from 24.75 µm to 33 µm with an average of 28.22 µm (Table 6).

The sieve-tube elements are characterized by simple sieve plates, placed on slightly inclined to transverse end walls (Plate X D). They also possess lateral sieve areas on their lateral walls (Plate X D). Sieve-elements are arranged in stratified manner (Plate XE). The length of sieve-tube elements varies from 173.25 µm to 222.75 µm with an average of 190.40 µm, whereas, the width from 16.50 µm to 24.75 µm with an average of 17.92 µm (Table 7). The sieve elements are found in distinct groups of 9-15 cells alternating with discontinuous tangential bands of fibre fascicles and occupy about 13.62% area of the conducting phloem in transectional view (Plate X E & Table 5).

The axial parenchyma cells are more or less of the size of the sieve elements in transectional view. They occur between fibre fascicles and sieve elements, and form

about 65.36% transectional area of the conducting phloem (Table 5). The phloem parenchyma cells do not contain tannins/druses in conducting as well as nonconducting phloem.

The rays are homogeneous in nature, composed of only procumbent elements, and are stratified (Plate XC). They look uniseriate to triseriate in tangential longitudinal plane. They adopt almost straight radial path both in the conducting and the non-conducting phloem up to the innermost periderm. The rays do not proliferate, so no expansion tissue is formed. The ray cells do not contain druses or tannins both in the conducting and non-conducting zones. They occupy about 10.08% transectional area of the conducting phloem (Table 5). The height of the rays varies from 4-8 cells with an average of 6.64 cells (130.56 µm), while the width ranges from 1-3 cells with an average of 2.48 cells (37.44 µm) (Table 8). The rays are exclusively short and medium; the tall rays are lacking (Table 9). Uniseriate rays form 7%, biseriate 33%, and triseriate 60% of the total ray population (Table 10). On the other hand, frequency of different types of rays per mm^2 reveals that the uniseriate rays number 4.68 biseriate 21.87 and triseriate 39.28 per mm^2 (Table 11).

The secretory cells are about 7 times bigger than

a parenchyma cell. They are found in secondary phloem in groups of 2-9 cells and are scattered all over the bark (Plate XB). They secrete a red juice which gets converted into a red astringent gum on exposure. The secretory cells are also observed to contain lesser amount of tannins in the conducting region as compared to the non-conducting region.

The sclereids are entirely absent in the conducting and non-conducting regions and periderms (Table 12).

SAMANEA SAMAN (JACQ) MERR.

Macro-morphology:

The bark is dark grey, hard, rough and deeply fissured (Plate XID). The fissures are v-shaped and are both vertically and horizontally spread (Plate XID). The rhytidome is thick and includes many periderm layers that deviate outwards (Fig. 9A). Lenticels and ray expansion tissue are not seen (Plate X ID & Fig. 9A).

Blaze exposes the dark brown outer bark and pale yellow inner bark. Later they turn blackish brown colour on exposure. The outer crust of compact rhytidome of the bark sloughs off as hard and thick flakes of average surface area of 125x43 mm^2 with an average thickness of 4 mm.

Micro-morphology:

The total bark thickness is 16.6 mm at the tree circumference of 128 cm. The rhytidome is about 8.9 mm thick and constitutes 53.79% of the entire bark, whereas the secondary phloem measures about 7.7 mm making 46.21% of the entire bark (Table 3). The thick rhytidome comprises several discontinuous periderms leaving only two periderms running around the entire circumference (Fig.18B).

The discontinuity of the outer periderms is obviously caused by the pressure due to the increasing bole circumference, resulting in the formation of fissures of various depths and sizes. Each periderm consists of phellogen, phellem and phelloderm. The phellogen is single layered with more or less rectangular cells. The phellem is 1-6 layered. The phellem cells are thick-walled, suberized and flattened radially and arranged in compact radial rows. The phelloderm is multi-layered, the cells of which have thin non-suberized walls with inter-cellular spaces. These squarish and spherical parenchymatous cells are arranged in radial rows. Sclereids occur in the older part of the secondary phloem. The sloughing off of thebark takes place by the breakdown of the phellem cells due to the strain developed by the addition of more and more secondary tissue of the wood and bark. No lenticels are observed in the periderm.

The secondary phloem is distinguished into the conducting and the non-conducting zones. The average thickness of the conducting zone is 1.5 mm which occupies 19.48% of the secondary phloem and 8.86% of the total bark, while the non-conducting zone is measured as 6.2 mm constituting 80.52%of the secondary phloem and 37.35% of the total bark (Table 3 & 4).

The microscopic study of the conducting phloem zone shows that the fibres are mostly grouped into tangentially extended bands and the bands are almost at regular intervals giving the impression of growth marks. Between the two successive fibre bands are found the sieve-tube elements, associated companion cells and axial parenchyma. The narrow radial rays pass almost straight through the conducting zone, making their way between fibres bands (Fig. 18B). The non-conducting zone, distinctly possesses obliterated sieve-tube elements and companion cells, sclereids and the deflected rays (Fig. 18B).

The fibres are thick-walled and lignified. They occur more or less in discontinuous tangential bands (Fig. 18B). Each fibre band is 2-3 cells wide in transectional view. The fibres constitute about 13.63% of the total of the cross sectional area conducting phloem (Table 5). The fibres are occasionally segmented (Fig.24A). The length of fibres ranges from 66.00 µm to 1534. µm with an average of 1055.68 µm, while their width varies from 16.50 µm to 24.75 µm with an average of 17.92 µm(Table 6).

The sieve-tube elements possess compound sieve plates on deeply inclined end walls (Plate XII A). Lateral sieve areas are highly developed on the entire lateral walls

(Plate XIIA). The sieve-tube elements are arranged in a non-stratified order as seen in tangential longitudinal sections. The length of sieve-tube elements ranges from 99.00 µm to 297.00 µm with an average of 184.48 µm, whereas the width ranges from 33.00 µm to 49.50 µm with an average of 38.40 µm (Table 7). The sieve-tube elements occur in groups of 6-20 cells and surrounded by parenchyma cells (Plate XIIB). They occupy about 28.87% of the total cross sectional area of the conducting phloem (Table 5).

The axial parenchyma cells are more or less of the same size as that of sieve-tube elements in transections. They occur around the group of sieve-tube elements and associated companion cells. A very few parenchyma cells contain tannins both in the conducting and the non-conducting phloem. Some of the parenchyma cells assume prominence in the non-conducting phloem due to increasing in their size after division. The transectional area occupied by axial parenchyma is estimated to about 37.87% in the conducting phloem (Table 5).

The rays are homogeneous in nature, as they are composed of only procumbent cells. The rays appear uniseriate to tetraseriate in tangential longitudinal sections. As seen in transections the rays are fine and maintain a

straight radial path in the conducting phloem most of which resort to deflected path as they enter the non-conducting zone due to the divisions in the parenchyma cells (Fig. 18). The transectional area occupied by phloem rays is found to be 19.63% of the total conducting zone (Table 5). The height of rays ranges from 2 to 8 cells with an average of 5.87 cells (93.76 µm), whereas the width ranges from 1 to 4 cells with an average of 2.22 cells (32.22 µm) (Table 8). Analysis of the frequency of the rays with respect to their varying height in tangential longitudinal section of the conducting phloem shows that there only short rays are existing in total ray population (Table 9). As regards the seriation of rays, the uniseriate rays form 12%, biseriate 63%, triseriate 20% and tetraseriate 5% of the total number of rays (Table 10) and their frequency per mm^2 reveals that the uniseriate rays are 7.96 biseriate 40.46, triseriate 12.18 and tetraseriate 2.49 per mm^2 (Table 11).

The sclereids are totally absent in the conducting pholem, but occur in groups of varying magnitudes and also as isolated elements in the non-condcuting phloem in addition to fibres fascicles. The sclereids are recognized as brachy-type (Fig. 24A). The length of sclereids ranges from 57.75 µm to 115.50 µm with an average of 54.15 µm,

whereas the width from 16.50 µm to 49.50 µm with an average of 34.56 µm (Table 12). The area occupied by sclereids is 10.55% of the total non-conducting phloem and phelloderm zones (Table 13).

SARACA INDICA L.

Macro-morphology:

The bark is dark brown to grey or almost black with warty surface, soft, and entire i.e. without fissures (Plate X IA). The rhytidome is thin and includes a thin single superficial periderm. The ray expansion tissue appears as fusiform and small narrow wedge shaped (Fig.9B). The lenticels are placed horizontally on the bole surface, about 5.5 lenticels per cm^2.

The bark when blazed, exposes the creamy or pale-yellow surface which changes into reddish brown on exposure. The bark exfoliates as minute scales with an average thickness of 0.5 mm and surface area of 2.7x1.3 mm^2, and also in powdery form.

Micro-morphology:

As a whole the bark has a depth of 4.5 mm in a tree trunk of 55 cm circumference. The rhytidome is thin and measures about 0.5 mm which constitutes about 11.10%, whereas, the overall thickness of the secondary phloem is about 4 mm which constitutes 88.90% of the total bark (Table 3).

The rhytidome consists of a single superficial periderm and is spread over the entire circumference. The periderm comprises all the three main constituents i.e.,

phellogen, phellem and phelloderm. The phellogen is single layered having more or less rectangular cells. The phellem forms a narrow zone of thin walled suberized cells. These cells are somewhat widened radially and arranged in compact radial rows. The multi-layered phelloderm zone occupies most of the periderm. It contains almost squarish and spherical, non-suberized parenchymatous cells which are arranged in radial rows with intercellular spaces. These cells are more or less of the size of cork cells. A large number of sclereids are found in groups of different shapes and sizes with the tendency to form tangential band amongst the phelloderm cells (Fig. 18C).

The secondary phloem is clearly zonated into conducting and non-conducting zones. The average depth of the conducting zone is found to be 0.8 mm which forms 20% of the total secondary phloem and 17.80% of the total bark, whereas the depth of the non-conducting zone is 3.2 mm thus constituting 80% of the secondary phloem and 71.01% of the total bark (Table 3 & 4).

The microscopic study of conducting phloem further reveals that the phloem component cells include sieve-tube elements, associated companion cells, axial parenchyma and fibres. The fibres form groups which in turn tend to form

discontinuous tangential bands. Between two successive bands lie the sieve elements with their associated companion cells and axial parenchyma. The rays are fine and run radially straight in the conducting zone, making way between the adjacent fibre fascicles. The non-conducting phloem, on the other hand, differs in having obliterated or crushed sieve-tube elements, crushed or cleared companion cells, sclereids and dilated rays. The rays dilate and deviate from straight path, as they approach the outer portion of the phloem (Fig. 18C).

The fibres are thick-walled and well lignified. They constitute the major part of the secondary phloem. They are grouped in small fascicles of 2-3 cells in width. These fibres fascicles do not show any regular arrangement (Fig. 18C). They constitute about 16.27% of the conducting phloem (Table 5). The fibres are normal, at times with serrated, dentated & forked apices (Fig. 24B). The length of fibres ranges from 445.50 µm to 1930.50 µm with an average of 1083.36 µm, whereas the width varies from 8.25 µm to 33 µm with an average of 16.16 µm (Table 6).

The sieve-tube elements have compound sieve-plates borne on deeply inclined end walls and or non-stratified (Plate XIB). They also possess well defined sieve areas

on their lateral walls (Plate X IB). The length of sieve-tube elements ranges from 189.75 µm to 594 µm with an average of 380.96 µm, while the width ranges 24.75 µm to 36.30 µm with an average of 35.55 µm (Table 7). They are found in groups of 5-12 cells and occupy 40.79% area of the conducting region in transectional view (Plate XIC & Table 5).

The cells of the axial parenchyma are comparatively smaller in size than the sieve-tube elements in cross-sectional view. They occur surrounding the groups of sieve-elements and the associated companion cells (Plate XIC). They form about 20.12% of cross sectional area of the total conducting phloem (Table 5). These cells contain tannins in the conducting as well as non-conducting region but in the ray expansion tissues.

The rays are homogeneous in nature as they are composed of only procumbent cells. The rays are fine and are non-stratified. They are uniseriate or biseriate. They mostly proliferate in the non-conducting outer phloem the proliferation being more pronounced near the periderm, producing small, and narrow wedge - shaped expansion tissue (Fig. 18C). The ray cells contain tannins both in the conducting and the non-conducting zones. The phloem rays occupy 22.82% area of total conducting phloem in transectional

view (Table 5). The height of rays ranges from 6 to 21 cells with an average of 12.50 cells (318.88 µm), whereas the width varies from 1 to 2 cells with an average of 1.70 cells (39.36 µm) (Table 8). Analysis of the frequency of rays with varying height shows that short rays form 30%, medium 60% and tall 10% of the rays in the conducting zone (Table 9). Similarly, the uniseriate rays form 41% and biseriate 59% of the total ray population (Table 10) The uniseriate rays number 13.43 and biseriate 19.52(Table 11).

The sclereids are totally absent in the conducting phloem, but appear in groups of various shapes and sizes in the non-conducting region and in the phelloderm in the form of irregular tangential bands (Fig. 18C). The length of the sclereids ranges from 49.50 µm to 165 µm with an average of 87.95 µm, whereas the width varies from 16.50 µm to 82.50 µm with an average of 42.90 µm (Table 12). The area occupied by sclereids is 23.03% of the non-conducting zone and the phelloderm (Table 13).

SESBANIA GRANDIFLORA PERS.

Macro-morphology:

The bark on the lower part of the main trunk is nearly black, soft, rough and shallow-fissured (Plate XIIC) whereas it is pale white smooth and entire, i.e., without fissured in the upper part and branches. The fissures are v-shaped and the ray expansion tissue is seen as small narrow wedge shaped commencing from the outer part of the non-conducting region of the secondary phloem upto the periderm (Fig. 10A). The rhytidome is thin and includes a successive periderm layers that run parallel to the cambium for a short distance and then deviate outwards (Fig. 10A). Lenticels are seen at the place of cracks.

When the bark is blazed, it exposes light red slightly white-streap inside. The bark is found flaked out irregularly in patches with an average of thickness of 1 mm and surface area of 6.6x2.2 mm^2.

Micro-morphology:

The total thickness of bark is 6.7 mm in a tree trunk of 41.5 cms circumference. The rhytidome measures 2.2 mm in depth and represents 32.84% of the total bark, whereas the total thickness of secondary phloem is found to about

4.5 mm which constitutes 67.16% of the total bark(Table 3).

The rhytidome comprises a periderm around the entire circumference and a number ofbroken periderms between the fissures. This discontinuity of the outer part of rhytidome is caused by the pressure exerted by increasing base circumference. The breaks in the periderms persist on the tree trunk for long, this results the formation of fissures of various sizesand shapes. This delayed flaking out of periderms, however occurs incipiently through phellem. Each periderm consists of phellogen, phellem and the phelloderm. The phellogen is single layered with rectangular cells in cross-section. Phellem is a multi-layered zone of thick walled, suberized cells, which are somewhat flattened radially and arranged in compact radial rows. The phelloderm is also many layered, the cells of which have non-suberized walls. They are squarish and rectangular parenchymatous cells with intercellular spaces and arranged in radial rows. The phelloderm cells are more or less similar in size to phellem cells. A small number of sclereids in groups of varying magnitude are found among the outer non-conducting phloem zone and phelloderm cells (Fig. 19A).

The secondary phloem differentiates into the conducting and the non-conducting zones. The average depth of

the conducting zone is 0.7 mm which forms 15.56% of the secondary phloem and 10.45% of the entire bark, whereas, the depth of the non-conducting zone is found to be 3.8mm constituting 84.44% of the secondary phloem and 56.71% of the entire bark (Table 3 & 4).

The detailed study of conducting phloem tissues reveals that the fibres are grouped in tangentially extended bands. Alternating with fibre bands are the sieve elements with their associated companion cells and axial parenchyma. The rays are mostly broad and are radially running almost straight up to the end of the conducting phloem. The non-conducting phloem, on the other hand, persists with obliterated or crushed sieve-tube elements and companion cells while the axial parenchyma remains unchanged. In addition sclereids appear and rays get dilated (Fig.19A).

The fibres are thick walled and lignified. They are the major supporting components of secondary phloem and are arranged in regular tangential bands and appear at regular intervals in the conducting phloem (Fig. 19A). But the ray disturb in non-conducting phloem due to the proliferation of the tissues (Fig. 19A). The width of a fibre band is 2-4 cells in transectional view and the fibres constitute about 17.48% area of the conducting phloem (Table 5).

Usually the fibres apices are smooth and tapering and rarely the fibres are septated (Fig. 24C). The length of fibres ranges from 660 µm to 1930.50 µm with an average of 1201.76 µm, while width from 16.50 µm to 24.75 µm with an average of 20 µm (Tbale 6).

The sieve-tube elements are characterized by simple sieve-plates, situated on slightly inclined end walls with slime plugs (Plate XIID). Lateral sieve areas are not prominent on the lateral walls. The sieve elements are arranged in a stratified pattern (Plate XIID). The length of sieve elements ranges from 165 to 264 µm with an average of 194.56 µm, whereas, the width from 33.0 µm to 41.25 µm with an average of 32.16 µm (Table 7). The sieve elements are arranged in groups of 2-9 cells between the fibre bands and occupy 15.89% of cross sectional area of the conducting phloem (Plate XIIIC & Table 5).

The axial parenchyma is more or less similar in size to sieve elements in transverse plane. They are found intermingled with phloem fibres, sieve elements and companion cells and form about 45.33% of cross sectional area of the conducting phloem (Table 5). The phloem parenchyma is devoid of tannins both in the conducting and the non-conducting zones.

The rays are homogeneous in nature as they are composed of only procumbent cells. They are uni to tetraseriate. In cross-sectional view they take almost straight radial run in the conducting phloem and adopt to deflection only in the non-conducting phloem. Most of the cells of the rays in the non-conducting phloem resort to proliferation to coup with the increasing circumference resulting in dilation of rays and formation of small wedge-shaped ray expansion tissue. The axial parenchyma close to the periderm, also proliferate for the same purpose. Tannins are not detected in the ray cells of both the conducting and the non-conducting phloem. The rays occupy about 21.30% area of the conducting phloem in transection (Table 5). The height of rays is found to range from 4-9 cells with and average of 5.74 cells (126.40 µm), while the width from 1-3 cells with an average of 2 cells (41.6 µm) (Table 8). As to the frequency of the rays with respect to height, only short rays are found while the medium and tall rays are missing in tangential longitudinal sections of the total ray population (Table 9). Regarding the width of rays, the uniseriate rays form 12%, biseriate 65% and triseriate 23% of the total number of rays (Table 10). On the other hand, the frequency of various types of rays per mm^2 in tangential longitudinal view in the conducting phloem comes to 4.33

for the uniseriate ray, 24.47 for biseriate rays and 8.68 per mm^2 for the triseriate (Table 11).

The sclereids are completely absent in the conducting phloem, but appear in the non-condcuting phloem in the form of groups of different sizes,in addition to fibre groups and occupy about 18.49% of total area of the non-conducting phloem and phelloderm (Table 13).Sclereids are brachy-type and their shape are hexagonal (Fig. 24C). The length of the sclereids ranges from 33 µm to 165 µm with and average of 69.60 µm, whereas the width from 33 µm to 90.75 µm with an average of 48.80 µm (Table 12).

TAMARINDUS INDICA L.

Macro-morphology:

The bark appears slate-grey or light brown, hard rough and shallow fissured (Plate XIIIA). The fissures run both vertically and horizontally but they are irregularly scattered over the entire bole surface. The rhytidome is thick and includes many overlapping periderm layers which run short distances tangentially. The ray expansion tissue and the lenticels are not visible.

From the surface of the bark fissures reddish powder is seen coming out, which replaces exfoliations of the bark. The bark peels in small irregular pieces of the average surface area of 68.5x30.7 mm^2 with an average thickness of 2.8 mm.

Micro-morphology:

The bark, as a whole is 10.5 mm in depth in the trunk of a 360 cm circumference. The rhytidome measures about 4 mm in thickness and over-all depth of secondary phloem is about 6.5 mm; as such they constitute 38.10% and 61.90% of the total bark respectively (Table 3).

The rhytidome is made up of multiple periderms. They leave two periderms around the entire circumference with-

out any crack (Fig. 19B). The distance between two periderms is not uniform. However, they varies from 262.07 µm to 1310.34 µm. However, the periderms run more or less parallel to each other (Fig. 19B). The outer periderms break at several places due to pressure exerted by the increasing bole circumference. They slough off through the phellem from the zone of the non-conducting phloem (Table 19B). Structurally, each periderm includes its own phellogen, phellem and phelloderm. The phellem forms a 2-3 layered zone of thick walled suberized cells arranged in compact radial rows. The phelloderm is multi-layered, the cells of which are non-suberized rectangular and arranged in radial rows without intercellular spaces. Most of the phelloderm cells contain tannins and assume larger dimensions as compared to cork cells. Sclereids are brachy type and form multiple layers and are arranged in regular tangential bands in the non-conducting zone (Fig. 19B). Since, sloughing of the bark takes place along the phellem in small and irregular pieces, the lenticels are not observed in the newly formed periderms.

The secondary phloem is well distinguished into the condcuting and the non-conducting zones. The average depth of conducting phloem measures to 1.5 mm making 23.08% of the secondary phloem and 14.28% of the total bark,while the

non-conducting region is 5 mm in depth which constitutes 76.92% of the total secondary phloem and 47.62% of the total bark (Table 3 & 4).

The microscopic study of conducting phloem reveals that the fibres are scattered in small groups. The sieve-tube elements are scattered between the fibres with their accompanied companion cells and axial parenchyma with narrow rays running almost straight into the non-conducting phloem (Fig. 19B). The non-conducting phloem on the other hand, possesses obliterated or collapsed sieve tubes and companion cells and the sclereids.

Fibres are thick walled and lignified. Each fibre group is 2-4 cells wide in cross section. These fibre fascicles do not show any regular arrangement (Fig.19B). The area occupied by fibres constitutes about 13.26% of the area of conducting phloem (Table 5). The fibre apices are occasionally dented (Fig. 24D). The length of fibres ranges from 552.75 to 1287 µm with an average of 900.96µm, while their width varies from 16.50 to 24.25 µm with an average of 16.16 µm (Table 6).

The sieve-tube elements possess compound sieve plates on deeply inclined end walls (Plate XIIIB). Sieve areas are highly developed on the entire lateral walls (Plate XIIIB).Sieve-tube elements are arranged in a non-stratified order as viewed in tangential longitudinal

sections. The length of sieve-tube elements fall in the range of 115.50 and 363 µm with an average of 240 µm, whereas the width is in the range of 19.80 and 33 µm with an average 26.88 µm (Table 7). Sieve-tube elements occur in groups of 2-5 cells and occupy 16.99% of the conducting phloem in transectional view (Plate XI I ID & Table 5).

The axial parenchyma cells are comparatively smaller than the sieve-tube elements as seen in transectional view. The cells occur associated with sieve-tube elements and companion cells and fibres in a randomized manner (Plate XIIID). The axial parenchyma occupies about 44.60% of transectional area of the conducting phloem (Table 5). Tannins are observed in a limited number of parenchyma cells in the conducting phloem, however, their presence is more marked in most of the non-conducting phloem cells.

The rays are homogeneous as they are made up of procumbent cells. They are uniseriate, biseriate and triseriate. They fine rays run more or less straight and take a slightly deflected path only in the outer non-conducting phloem as seen transections (Fig. 19B). The phloem rays form about 25.15% of the total conducting phloem in cross sectional plane (Table 5). The ray height ranges

from 5-16 cells with an average of 11.20 cells (186.11 m), while the width varies from 1-3 cells with an average of 2.18 cells (29.92 µm) (Table 8). The frequency of rays of varying height in the conducting phloem changes. Short rays occupy 42% and medium 58% of the total ray population (Table 9). Similarly, uniseriate raysoccupy 13%, biseriate 5 1% and triseriate 36% of their total number (Table 10). As to the frequency of different types of rays per mm^2 the uniseriate rays are numbered 7.65, biseriate 31.40 and triseriate 22.24 per mm^2 (Table 11).

The sclereids are completely missing in the conducting phloem, but occur in tangential band in the non-conducting phloem in addition to fibre fascicles. The sclereids are distinguished as brachy-tupe (Fig. 24D). The length of the sclereids ranges from 33 to 132 µm, while the width ranges from 24.75 to 66.00 µm with an average of 38.08 µm (Table 12). The amount of sclereids is determined to be about 41.62% (Table 13) of the entire non-conducting phloem and phelloderm.

Table - 3: The depth of various zones of the bark in different species

Name of the species	Total bark (mm)	Secondary phloem (mm)	Conducting phloem (mm)	Non-conducting phloem (mm)	Rhytidome (mm)
Acacia farnesiana	3.0	2.0 (66.67%)	0.6 (18.67%)	1.4 (48.00%)	1.0 (33.33%)
Cassia fistula	18.5	11.7 (63.24%)	0.7 (3.78%)	11.0 (59.46%)	6.8 (36.76%)
C. javanica	7.7	7.2 (93.51%)	0.7 (9.09%)	6.5 (84.42%)	0.5 (6.49%)
C. nodosa	14.5	14.0 (96.55%)	2.5 (17.24%)	11.5 (79.31%)	0.5 (3.45%)
C. renigera	24.0	5.8 (24.17%)	1.0 (4.17%)	4.8 (20.00%)	18.2 (75.83%)
C. siamea	6.0	5.3 (88.26%)	0.4 (6.60%)	4.9 (81.66%)	0.7 (11.66%)
Delonxi regia	4.4	3.4 (77.28%)	0.6 (13.64%)	2.8 (63.64%)	1.0 (22.72%)
Erythrina indica	10.5	10.3 (98.10%)	0.5 (4.77%)	9.8 (93.33%)	0.2 (1.90%)
E. suberosa	22.5	6.3 (27.88%)	1.2 5.31%)	5.1 (22.57%)	16.3 (72.12%)
Gliricidia maculata	7.0	5.6 (80.00%)	1.7 (24.28)	3.9 (55.72%)	1.4 (20.00%)
Hardwickia binata	12.0	8.6 (71.66%)	0.8 (6.66%)	7.8 (65.00%)	3.4 (28.34%)
Parkia roxburghii	12.9	10.6 (82.17%)	2.4 (18.60%)	8.2 (63.57%)	2.3 (17.83%)
Peltophorum pterocarpum	8.5	6.0 (70.58%)	1.0 (11.76%)	5.0 (58.82%)	2.5 (29.42%)
Prosopis juliflora	9.2	5.2 (56.52%)	0.7 (7.61%)	4.5 (48.91%)	4.0 (43.48%)
Pterocarpus marsupium	13.0	6.2 (47.84%)	0.7 (5.38%)	5.5 (42.46%)	6.8 (52.16%)
Samanea saman	16.6	7.7 (46.21%)	1.5 (8.86%)	6.2 (37.35%)	8.9 (53.79%)
Sirasa indica	4.5	4.0 (88.90%)	0.8 (17.80%)	3.2 (71.10%)	0.5 (11.10%)
Sesbania grandiflora	6.7	4.5 (67.16%)	0.7 (10.45%)	3.8 (56.71%)	2.2 (32.84%)
Tamarindus indica	10.5	6.5 (61.90%)	1.5 (14.28%)	5.0 (47.62%)	4.0 (38.10)

Table - 4

Proportion of conducting and non-conducting phloem in the Secondary phloem of different species

Name of species	Secondary	
	Conducting phloem (%)	Non-conducting Phloem (%)
Acacia farnesiana	28.00	72.00
Cassia fistula	5.98	94.02
C. javanica	9.72	90.28
C. nodosa	17.86	82.14
C. renigera	17.24	82.76
C. siamea	7.55	92.45
Delonix regia	17.65	82.35
Erythrina indica	4.85	95.15
E. suberosa	19.05	80.95
Gliricidia maculata	30.36	69.64
Hardwickia binata	9.30	90.70
Parkia roxburghii	22.64	77.36
Peltophorum pterocarpum	16.67	83.33
Prosopis juliflora	13.46	86.54
Pterocarpus marsupium	11.25	88.75
Samanea saman	19.48	80.52
Saraca indica	20.00	80.00
Sesbania grandiflora	15.56	84.44
Tamarindus indica	23.08	76.92

Table - 5

Proportion of different phloic components in the conducting phloem of different species based on tangential area.

Name of species	Fibres (%)	Sieve tube elements(%)	axial paren-chyma (%)	Rays (%)
Acacia farnesiana	18.39	29.04	36.82	15.75
Cassia fistula	13.59	14.82	52.57	19.02
C. javanica	11.69	11.78	61.48	15.05
C. nodosa	22.47	15.13	47.25	15.15
C. renigera	12.56	17.40	56.43	13.61
C. siamea	13.35	7.19	64.50	14.96
Delonix regia	7.06	54.63	18.72	19.59
Erythrina indica	5.96	27.49	38.75	27.80
E. suberosa	8.45	20.37	37.85	33.33
Gliricidia maculata	10.09	15.98	53.58	20.35
Hardwickia binata	10.34	6.01	65.74	17.91
Parkia roxburghii	10.04	10.62	54.54	24.92
Peltephorum pterocarpum	14.23	8.36	61.05	16.36
Prosopis juliflora	12.30	26.78	46.44	14.48
Pterocarpus marsupium	10.94	13.62	65.36	10.08
Samanea saman	13.63	28.87	37.87	19.63
Saraca indica	16.27	40.79	20.12	22.82
Sesbania grandiflora	17.48	15.89	45.33	21.30
Tamarindus indica	13.26	16.99	44.60	25.15

Table - 6

Dimension of fibres in the secondary phloem of different species

Name of species	Length (µm) ± SD	Width (µm) ± SD
Acacia farnesiana	1198.56 ±197.32 (832.00 - 1664.00)	20.77 ±3.25 (16.50 - 33.00)
Cassia fistula	839.52 ±222.94 (368.00 - 1280.00)	19.68 ±6.03 (16.50 - 33.00)
C. javanica	650.88 ±181.72 (280.50 - 973 .50)	20.00 ±6.04 (16.50 - 33.00)
C. nodosa	637.76 ±169.64 (346.50 - 1023.00)	23.20 ±5.71 (16.50 - 33.00)
C. renigera	592.80 ±138.68 (364.50 - 891.00)	19.84 ±5.36 (16.50 - 33.00)
C. siamea	995.36 ±210.08 (610.50 - 1551.00)	19.60 ±5.99 (16.50 - 33.00)
Delonix regia	1742.08 ±632.17 (841.50 - 3613.50)	18.08 ±3.86 (16.50 - 33.00)
Erythrina indica	1599.36 ±496.82 (610.50 - 1975.00)	18.24 ±3.93 (16.50 - 33.00)
E. suberosa	1281.28 ±269.71 (627.00 - 1897.50)	31.20 ±2.40 (24.75 - 33.00)
Gliricidia maculta	770.56 ±192.77 (33.00 - 1204.50)	22.08 ±6.89 (16.50 - 41.25)
Hardwickia binata	1548.64 ±449.82 (544.50 - 2343.00)	12.22 ±3.99 (8.25 - 16.50)
Parkia roxburghii	1111.20 ±279.44 (429.00 - 1930.50)	14.56 ±3.08 (8.25 - 16.50)
Peltophorum pterocarpum	851.20 ±261.01 (346.50 - 1468.50)	16.32 ±1.57 (13.20 - 24.75)
Prosopis juliflora	976.64 ±231.02 (528.00 - 1369.50)	20.63 ±2.31 (16.50 - 24.75)
Samanea saman	1055.68 ±231.18 (66.00 - 1534.50)	17.92 ±0.21 (16.50 - 24.75)
Saraca indica	1083.36 ±294.73 (445.50 - 1930.50)	16.16 ±4.38 (8.25 - 33.00)
Sesbania grandiflora	1210.76 ±279.84 (445.50 - 1930.50)	20.00 ±5.98 (16.50 - 24.75)
Tamarindus indica	900.96 ±188.49 (552.75 - 1287.00)	16.16 ±3.86 (16.50 - 24.75)

Mean ± SD (Standard Deviation)

Figures within parentheses indicate the range.

Table - 7

Dimension of sieve-tube elements in the conducting secondary phloem

Name of the species	Length (µm)	Width (µm)
Acacia farnesiana	290.24 ±45.90 (198.00-379.50)	32.00 ±3.26 (16.50-48.50)
Cassia fistula	322.03 ±80.59 (160.00-456.00)	24.64 ±5.77 (16.50-35.20)
C. javanica	364.0 ±66.66 (247.90-495.00)	32.80 ±4.26 (24.75-41.25)
C. nodosa	259.20 ±55.70 (165.00-396.00)	28.80 ±3.92 (24.75-33.00)
C. renigera	269.60 ±49.29 (165.00-396.00)	40.16 ±4.10 (24.75-49.50)
C. siamea	353.22 ±91.42 (198.00-528.00)	31.58 ±6.64 (16.50-41.25)
Delonix regia	445.28 ±97.02 (280.50-726.00)	38.30 ±4.95 (33.00-52.80)
Erythrina indica	245.28 ±23.93 (214.50-313.50)	34.56 ±5.79 (24.75-49.50)
E. suberosa	353.16 ±93.79 (181.50-572.50)	36.19 ±36.32 (18.15-41.25)
Gliricidia maculta	189.76 ±15.52 (165.00-213.50)	21.00 ±4.31 (16.50-33.00)
Hardwickia binata	252.16 ±33.84 (198.00-333.00)	28.32 ±3.98 (24.75-33.00)
Parkia roxburghii	327.52 ±93.30 (156.75-561.00)	34.05 ±5.16 (16.50-33.00)
Peltophorum pterocarpum	351.36 ±88.44 (156.75-577.50)	27.78 ±4.32 (16.50-36.30)
Prosopis juliflora	224.64 ±40.09 (148.50-330.00)	19.23 ±3.64 (16.50-29.70)
Pterocarpus marsupium	190.40 ±12.99 (173.25-222.75)	17.92 ±3.42 (16.50-24.75)
Samanea saman	184.48 ±42.19 (99.00-297.00)	38.40 ±5.31 (33.00-49.50)
Saraca indica	380.96 ±104.16 (189.75-594.00)	35.55 ±45.36 (24.75-36.30)
Sesbania grandiflora	194.56 ±21.85 (165.00-264.00)	32.16 ±1.20 (33.00-41.25)
Tamarindus indica	240.00 ±66.57 (115.50-363.00)	26.88 ±3.59 (19.80-33.00)

Mean ± SD (standard Deviation)

Figures within parentheses indicate the range.

Table - 8

Mean height and width of rays in the conducting secondary phloem of different species

	Height in No.of cells	Height in µm	Width in No.of cells	Width in µm
Acacia farnesiana	23.12 ±8.636	329.60 ±125.126	4.04 ±0.598	54.08 ±15.428
Cassia fistula	10.59 ±4.173	211.04 ±82.856	1.24 ±0.427	20.64 ±7.971
C. javanica	8.36 ±1.834	1.48 ±36.059	2.40 ±0.489	39.20 ±8.705
C. nodosa	9.66 ±5.002	172.80 ±82.715	2.36 ±0.874	38.88 ±14.712
C. renigera	8.06 ±2.148	129.76 ±28.833	2.71 ±0.874	36.32 ±7.705
C. siamea	9.66 ±2.560	198.72 ±48.590	2.30 ±0.458	36.48 ±7.355
Pelonix regia	17.18 ±9.285	343.20 ±188.332	2.92 ±0.934	51.84 ±19.870
Erythrina indica	64.75 ±24.855	2384.80 +926.224	12.10 ±2.231	470.80 +66.36
E. suberosa	47.40 ±23.479	1350.40 ±41.991	10.20 ±4.147	297.60 ±125.270
Gliricidia maculata	6.32 ±1.152	147.20 ±21.995	2.04 ±0.397	38.40 ±10.123
Hardwickia binata	8.63 ±4.277	246.72 ±116.390	1.73 ±0.628	27.36 ±10.051
Parkia roxburghii	16.29 ±8.923	288.96 ±113.281	2.75 ±0.835	51.04 ±19.531
Peltophorum pterocarpum	10.76 ±3.114	182.88 ±42.139	1.18 ±0.387	18.90 ±5.984
Prosopis juliflora	16.65 ±7.555	230.08 ±96.657	3.22 ±1.100	34.56 ±13.574
Pterocarpus marsupium	6.64 ±1.015	130.56 ±19.689	2.48 ±0.574	37.44 ±9.028
Samanea saman	5.87 ±2.509	93.76 ±39.406	2.22 ±0.892	32.32 ±11.744
Saraca indica	12.50 ±4.492	318.88 ±107.345	1.70 ±0.458	39.36 +12.208
Sesbania grandiflora	5.74 ±1.293	126.40 ±27.433	2.00 ±0.400	41.60 ±10.089
Tamarindus indica	11.20 ±2.683	186.11 +35.067	2.18 ±0.554	29.92 ±9.359

Mean ± SD (Standard Deviation)

Table - 9

Percentage of rays of varying height in the conducting phloem of different species

Name of the species	Short (1-10 cells)	Medium (11-20 cells)	Tall (above-20 cells)
Acacia farnesiana	12.5	25.0	62.5
Cassia fistula	55.1	41.4	3.5
C. javanica	83.3	16.7	-
C. nodosa	53.4	43.3	3.3
C. renigera	92.0	8.0	-
C. siamea	68.0	32.0	-
Delonix regia	27.4	46.8	25.8
Erythrina indica	14.2	-	85.8
E. suberosa	26.0	-	74.0
Gliricidia maculata	100.0	-	-
Hardwickia binata	63.3	36.7	-
Parkia roxburghii	28.6	46.4	25.0
Peltophorum pterocarpum	48.6	51.4	-
Prosopis juliflora	22.9	52.1	25.0
Pterocarpus marsupium	100.0	-	-
Samanea saman	100.0	-	-
Saraca indica	30.0	60.0	10.0
Sesbania grandiflora	100.0	-	-
Tamarindus indica	42.0	58.0	-

Table - 10

Percentage of rays of varying width in the conducting of different species

Name of the species	Narrow				Broad		Total
	Unise-riate	Bise-riate	Trise-riate	Total	Tetra-seriate	Multis-eriate	
Acacia farnesiana	-	6	17	23	30	47	77
Cassia fistula	83	17	-	100	-	-	-
C. javanica	12	53	35	100	-	-	-
C. nodosa	5	40	55	100	-	-	-
C. renigera	10	34	56	100	-	-	-
C. siamea	3	71	26	100	-	-	-
Delonix regia	4	19	36	59	41	-	41
Erythrina indica	6	6	-	12	-	88	88
E. suberosa	3	3	7	13	-	87	87
Gliricidia maculata	18	48	31	97	3	-	3
Hardwickia binata	43	49	8	100	-	-	-
Parkia roxburghii	26	33	16	75	22	3	25
Peltophorum pterocarpum	89	11	-	100	-	-	-
Prosopis juliflora	17	29	31	77	23	-	23
Pterocarpus marsupium	7	33	60	100	-	-	-
Samanea saman	12	63	20	95	5	-	5
Saraca indica	41	59	-	100	-	-	-
Sesbania grandiflora	12	65	23	100	-	-	-
Tamarindus indica	13	51	36	100	-	-	-

Table - 11 Frequency of rays per mm² in the conducting phloem of different species based on observation made in T.L.S.

Name of the species	Narrow			Broad		No. of rays per mm²
	Uniseriate	Biseriate	Triseriate	Tetraseriate	Multiseriate	
Acacia farnesiana	-	1.60 (1.00-2.00)	2.67 (1.2-3.00)	2.67 (1.56-4.00)	4.28 (1.56-6.00)	11.22
Cassia fistula	48.12 (37.50-59.37)	9.99 (6.00-14.00)	-	-	-	58.11
C. javanica	4.99 (3.00- 7.80)	22.34 (14.00-34.00)	14.99 (4.68-21.88)	-	-	42.32
C. nodosa	2.18 (1.56-6.00)	16.25 (12.50-21.87)	22.49 (15.63-28.13)	-	-	49.92
C. renigera	4.52 (3.00-6.00)	15.62 (10.93-31.00)	25.15 (18.75-32.81)	-	-	45.29
C. siamea	1.09 (0.00-4.68)	30.93 (26.65-40.63)	11.24 (3.00-10.90)	-	-	53.26
Delonix regia	0.62 (0.00-3.00)	2.96 (0.00-9.00)	5.62 (0.00-9.00)	6.40 (3.00-9.00)	-	15.60
Erythrina indica	0.10 (0.00-1.00)	0.10 (0.00-1.00)	-	-	1.36 (1.00-2.00)	1.56
E. suberosa	0.16 (0.00-1.56)	0.16 (0.00-1.56)	0.42 (0.00-1.56)	-	1.67 (1.57-2.50)	2.41
Gliricidia maculata	12.88 (9.00-18.75)	33.59 (31.00-35.93)	21.98 (20.00-25.00)	3.12 (1.56-3.50)	-	71.57
Hardwickia binata	21.70 (9.00-29.68)	24.52 (18.75-34.00)	3.90 (1.56-7.80)	-	-	50.12
Parkia roxburghii	7.67 (1.78-14.00)	9.83 (6.00-14.00)	4.84 (0.00-9.00)	6.40 (3.00-10.90)	0.77 (0.00-3.00)	29.55
Peltophorum pterocarpum	49.37 (37.50-50.00)	6.40 (4.68-12.50)	-	-	-	55.77
Prosopis juliflora	5.31 (1.50-10.93)	8.90 (3.00-20.00)	9.68 (1.56-21.88)	7.03 (1.56-15.63)	-	30.92
Pterocarpus marsupium	4.68 (3.00-7.80)	21.87 (10.90-34.00)	29.28 (23.00-50.00)	-	-	65.83
Samanea saman	7.96 (1.56-14.00)	40.46 (20.56-56.00)	12.18 (6.00-18.75)	2.49 (1.56-4.68)	-	63.09
Saraca indica	13.48 (4.69-25.00)	19.52 (9.00-26.56)	-	-	-	32.95
Sesbania grandiflora	4.33 (1.56-7.81)	24.47 (7.80-34.00)	8.68 (4.00-14.00)	-	-	37.48
Tamarindus indica	7.65 (4.00-9.00)	31.40 (26. 0-42.00)	22.24 (14.00-32.00)	-	-	61.29

Table - 12

Dimension of sclereids in the secondary phloem of different species based on observations made of isolated elements.

Name of the species	Length(µm)	Width (µm)
Acacia farnesiana	54.78 ±11.139 (24.75-66.00)	34.52 ±9.612 (16.50-49.50)
Cassia fistula	104.16 ±50.430 (24.00-272.00)	48.70 ±14.837 (16.50-[illegible])
C. javanica	123.20 ±49.805 (40.00-272.00)	35.84 ±9.893 (16.00-66.00)
C. nodosa	113.76 ±54.990 (33.00-248.00)	41.98 ±15.106 (24.75-99.00)
C. renigera	73.60 ±19.320 (33.00 -107.25)	34.10 ±10.992 (33.00-66.00)
C. siamea	124.64 ±39.771 (66.00-240.00)	30.82 ±8.470 (16.50-49.50)
Delonix regia	90.75 ±27.619 (38.00-144.00)	36.64 ±10.088 (16.50-66.00)
Erythrina indica	98.08 ±57.037 (40.00-320.00)	42.08 ±11.013 (24.00-64.00)
E. suberosa	183.65 ±65.235 (66.00-313.50)	61.38 ±21.381 (33.00-99.00)
Gliricidia maculata	51.52 ±15.689 (33.00-99.00)	46.88 ±12.186 (33.00-82.50)
Hardwickia binata	61.88 ±10.378 (49.50-82.50)	46.69 ±13.184 (33.00-74.25)
Parkia roxburghii	63.20 ±26.494 (33.00-160.00)	37.76 ±7.584 (24.00-56.00)
Peltophorum pterocarpum	170.24 ±63.658 (80.50-330.00)	42.24 ±13.099 (24.78-80.25)
Prosopis juliflora	50.18 ±14.325 (24.75-66.00)	33.47 ±9.823 (16.50-49.50)
Pterocarpus marsupium	-	-
Samanea saman	54.15 ±14.976 (57.75-115.50)	34.56 ±8.068 (16.50-49.50)
Saraca indica	87.95 ±18.365 (49.50 -165.00)	42.90 ±12.821 (16.50-82.50)
Sesbania grandiflora	69.60 ±22.865 (33.00-165.00)	48.80 ±11.341 (33.00-90.15)
Tamarindus indica	69.76 ±29.762 (33.00-132.00)	38.08 ±9.643 (24.75-66.00)

Mean ± SD (Standard Deviation)

Figures within parentheses indicate the range.

Table - 13

Amount of sclereids in secondary phloem of different species as seen cross-sections

Name of the species	Sclereids(%)
Acacia farnesiana	9.11
Cassia fistula	11.95
C. javanica	9.74
C. nodosa	16.48
C. renigera	13.57
C. siamea	13.18
Delonix regia	27.50
Erythrina indica	2.32
E. suberosa	3.04
Gliricidia maculata	3.34
Hardwickia binata	1.50
Parkia roxburghii	4.12
Peltophorum pterocarpum	26.38
Prosopis juliflora	2.05
Pterocarpus marsupium	-
Samanea saman	10.55
Saraca indica	19.20
Sesbania grandiflora	2.65
Tamarindus indica	41.62

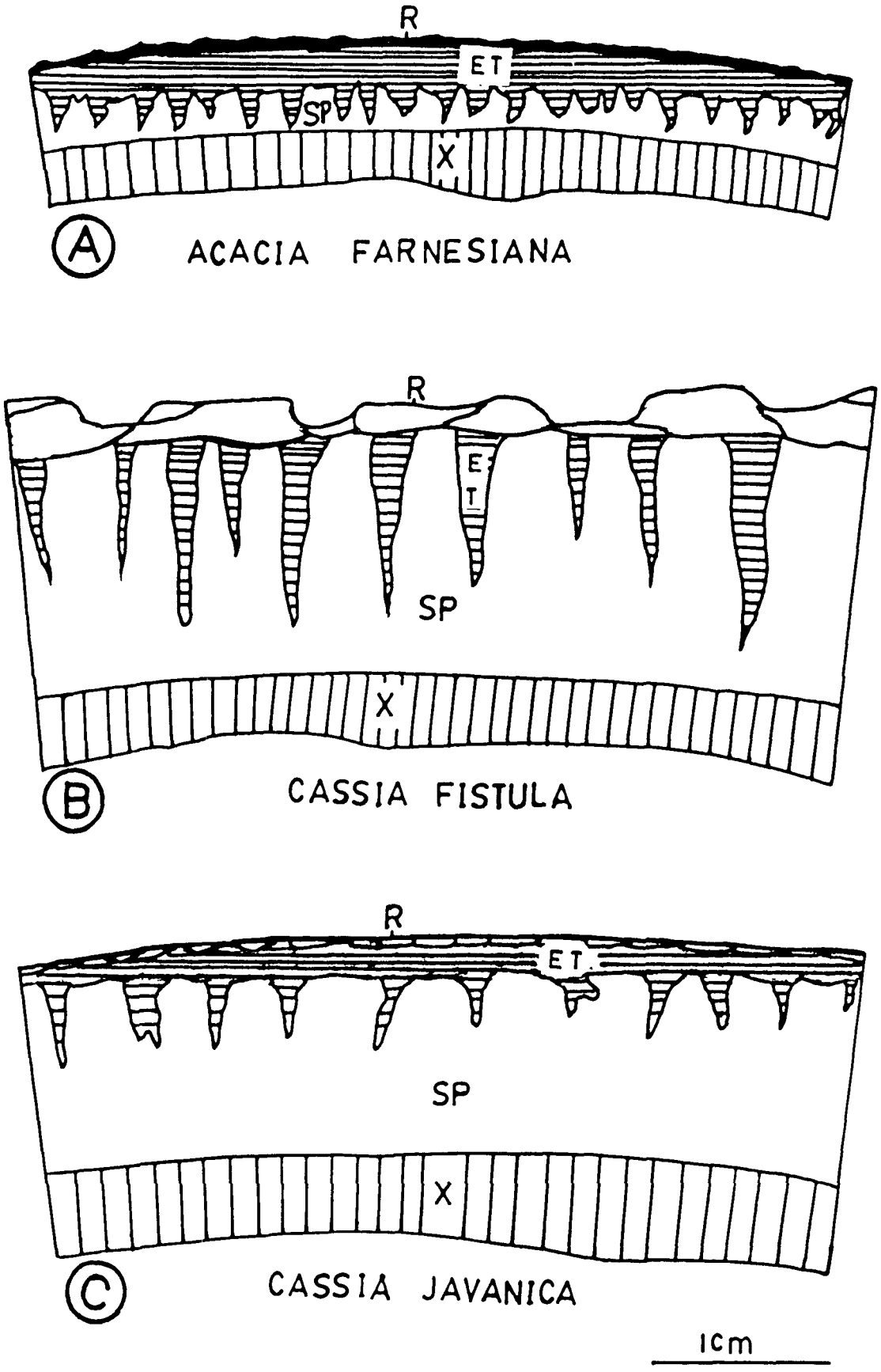


Fig. 3A-C. Slash surface showing fissuring pattern and gross structure of bark. R = Rhytidome, SP = Secondary phloem, ET = Expansion tissues, X = xylem.

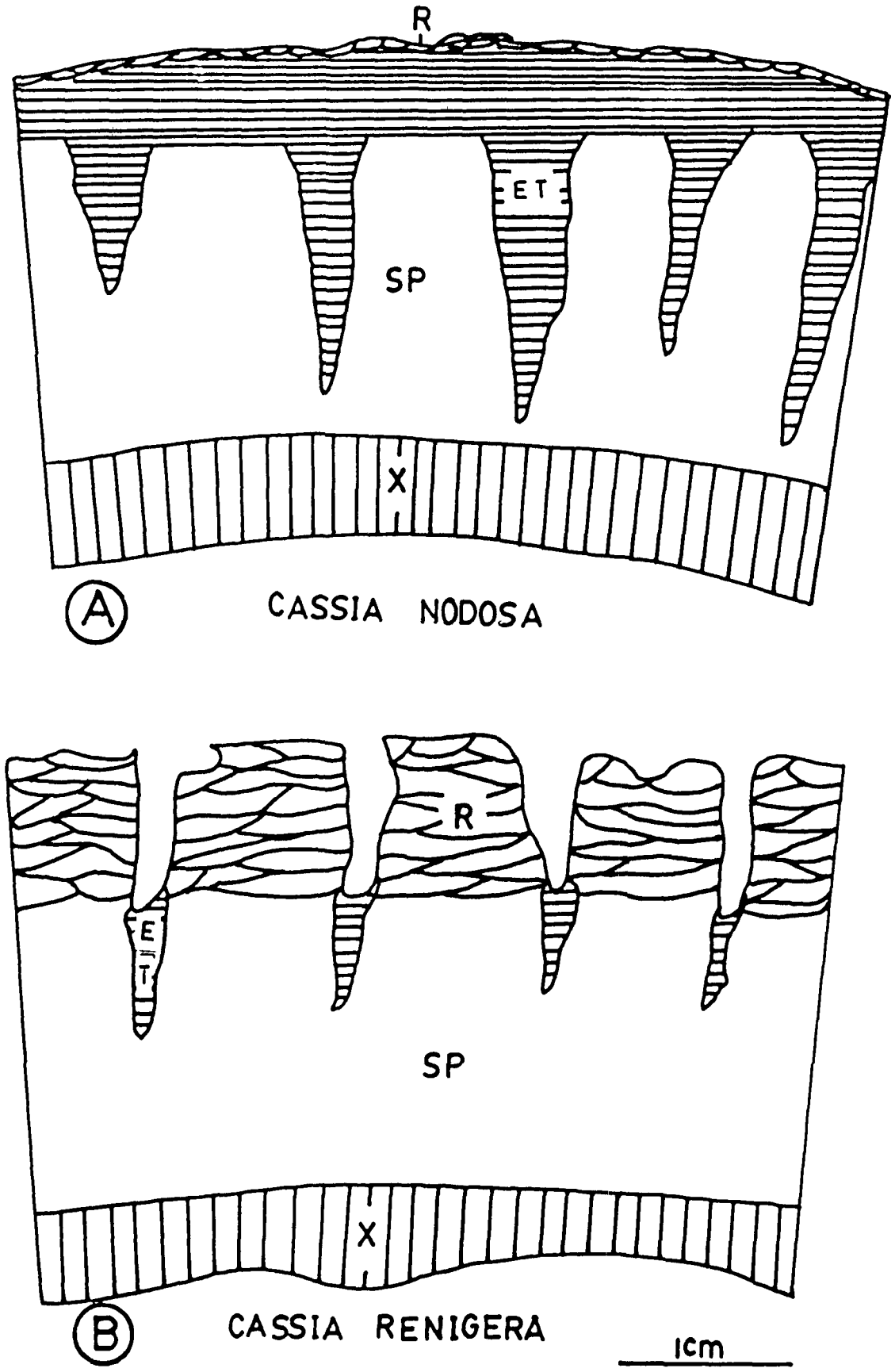


Fig. 4A-B. Slash surface showing fissuring pattern and gross structure of bark. R = Rhytidome, SP= Secondary phloem, ET=expansion tissues, X = Xylem.

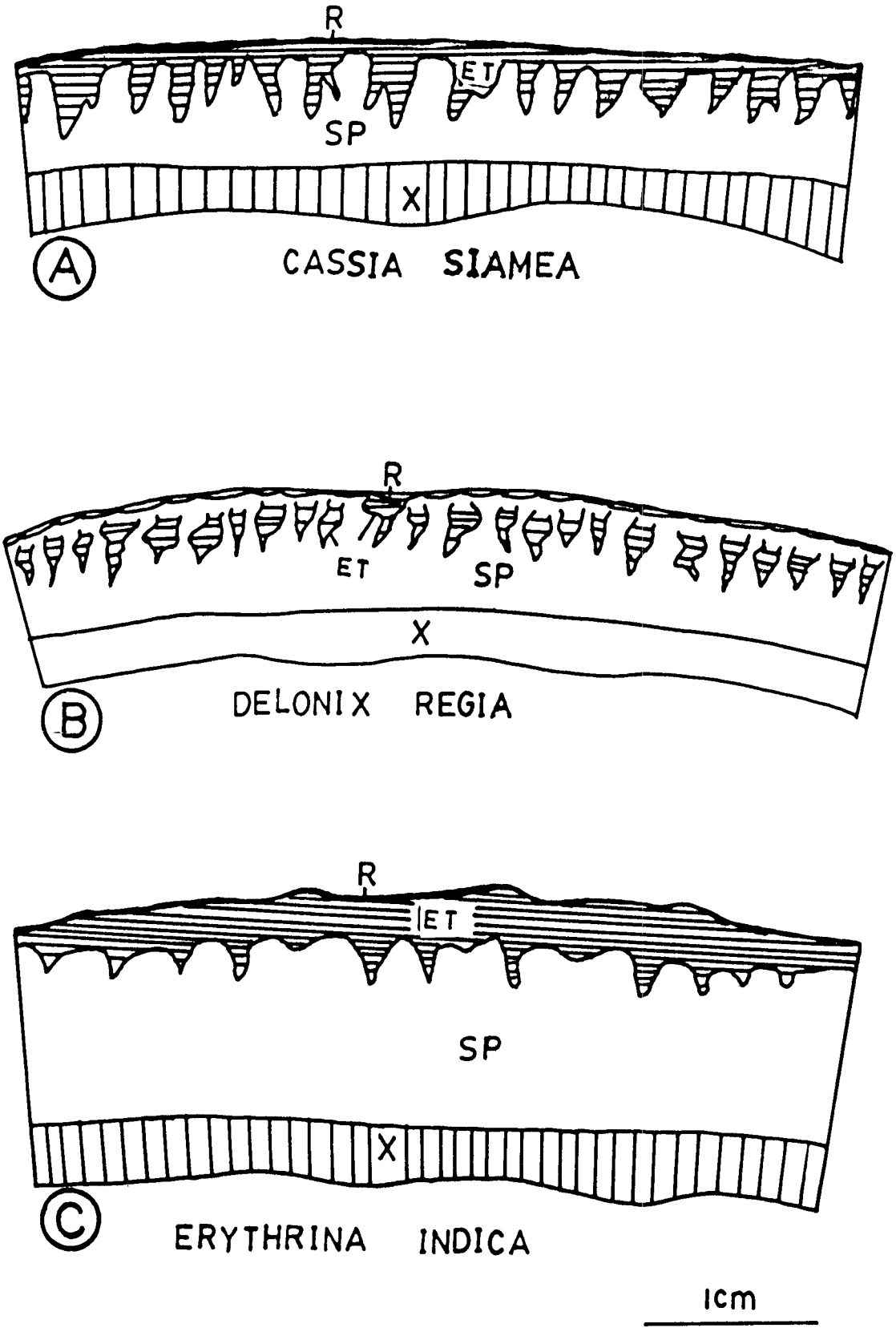


Fig. 5A-C. Slash surface showing fissuring pattern and gross structure of bark. R = Rhytidome, SP = Secondary phloem, ET = Expansion tissues, X = Xylem.

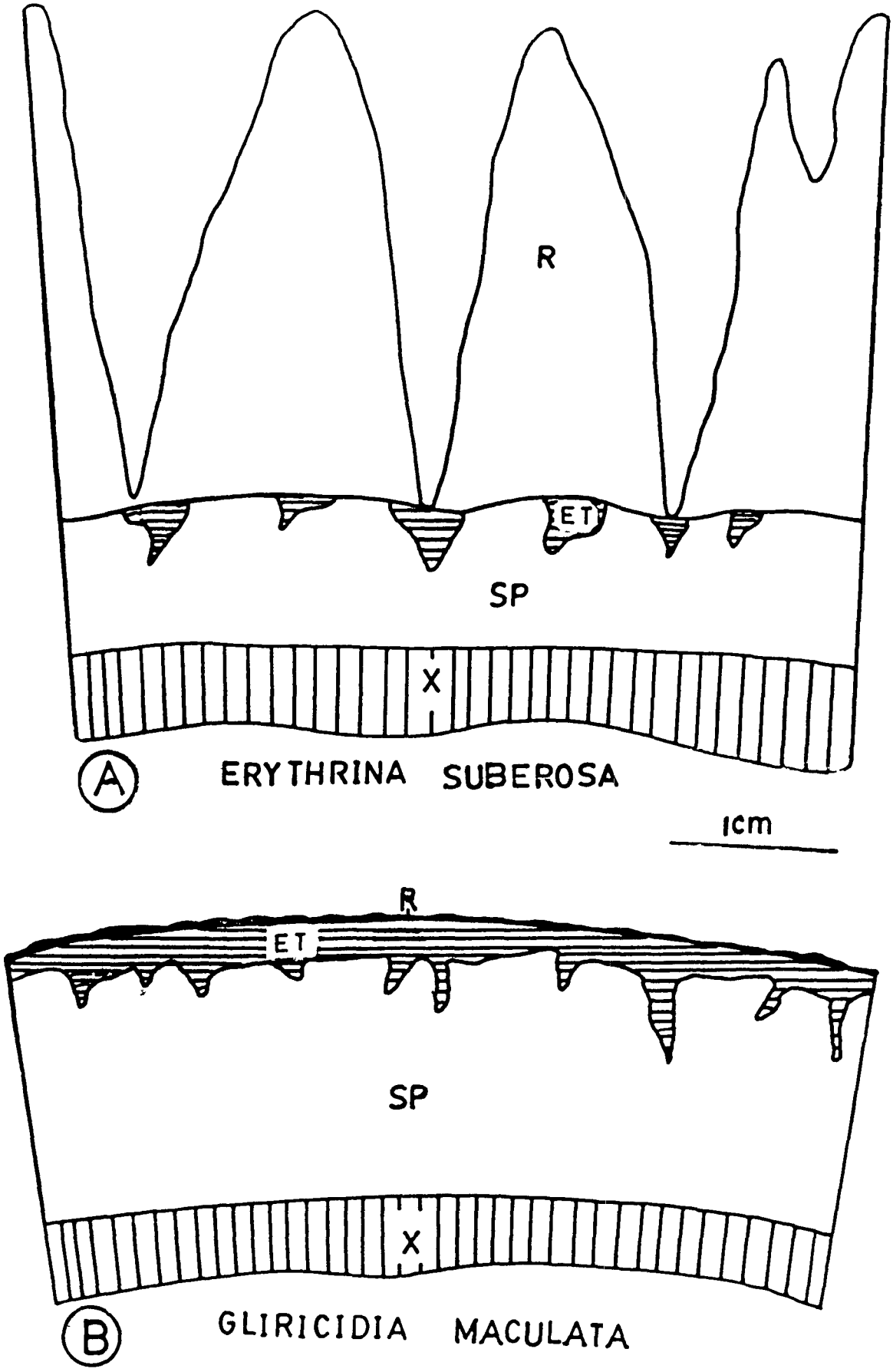


Fig. 6A-B. Slash surface showing fissuring pattern and gross structure of bark. R = Rhytidome, SP = Secondary phloem, ET = Expansion tissues, X = Xylem.

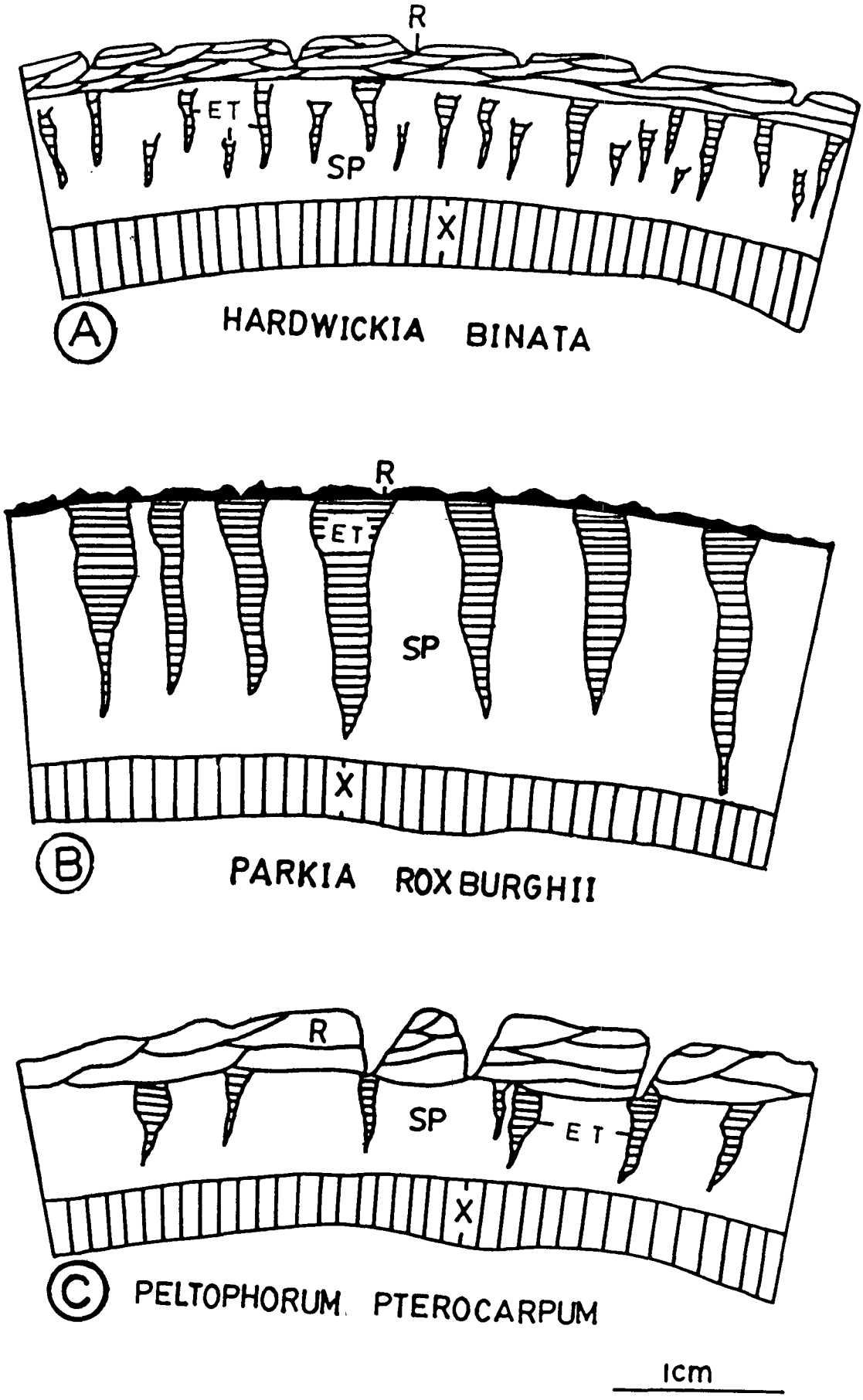
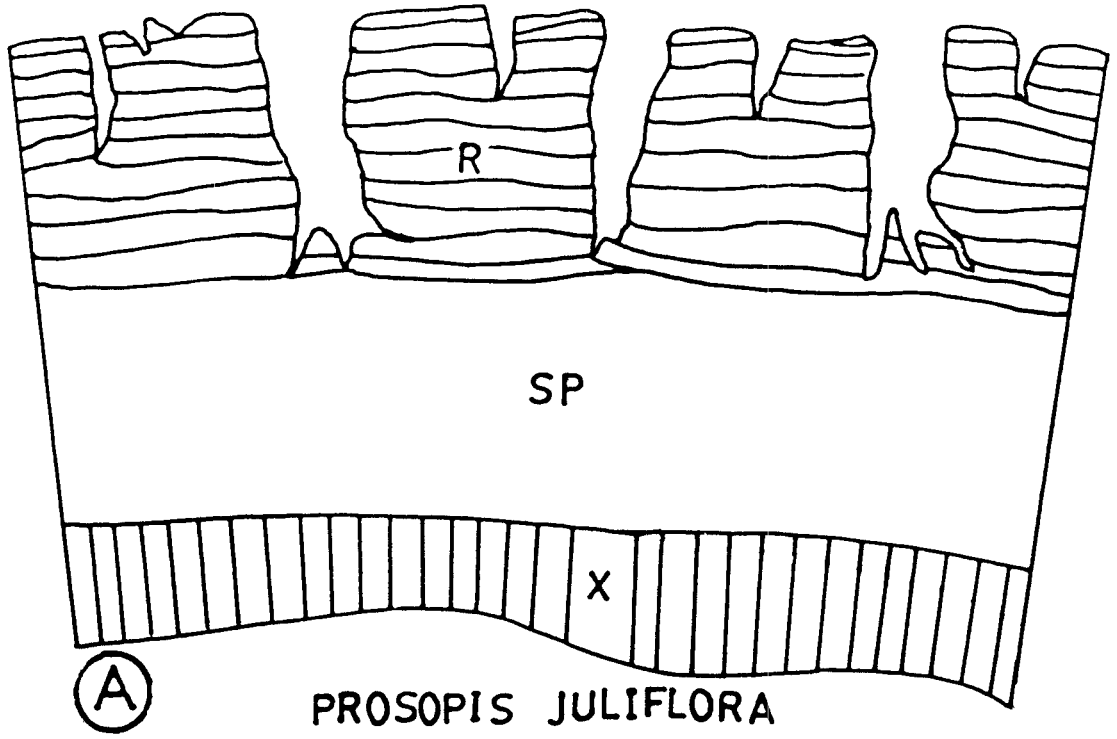


Fig. 7A-C. Slash surface showing fissuring pattern and gross structure of bark. R = Rhytidome, SP = Secondary phloem, ET = Expansion tissues, X = Xylem.



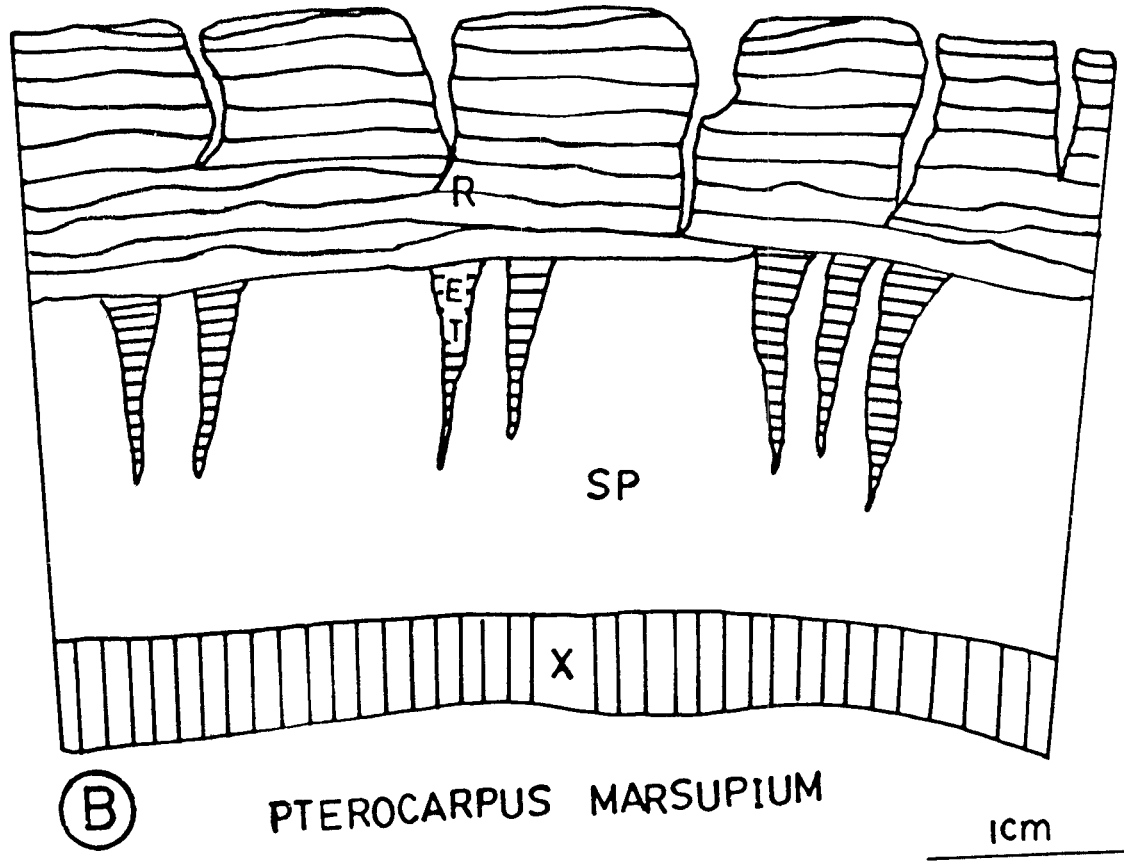


Fig. 8A-B. Slash surface showing fissuring pattern and gross structure of bark. R=Rhytidome, SP = Secondary phloem, ET = Expansion tissues, X = Xylem.

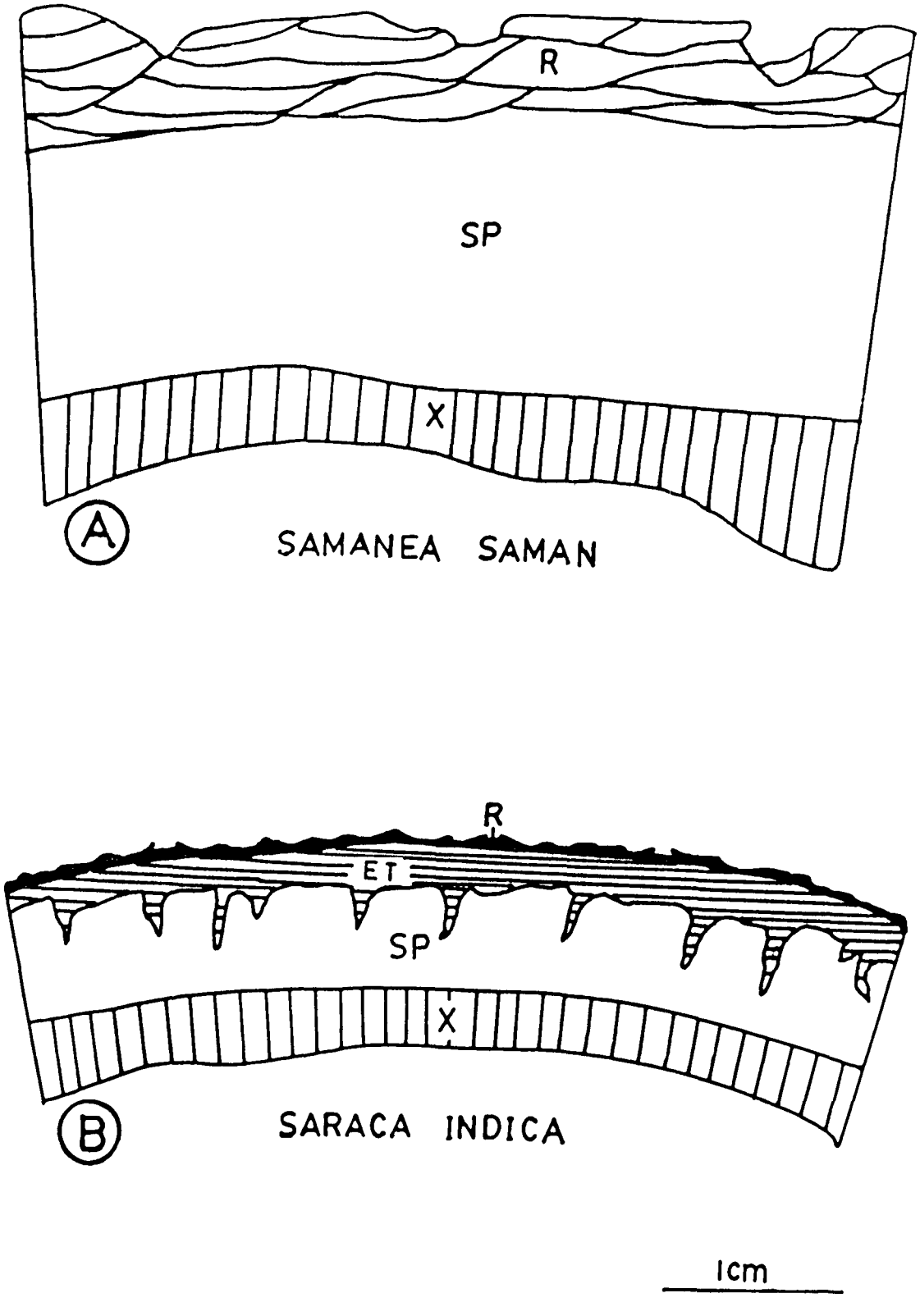


Fig. 9A-B. Slash surface showing fissuring pattern and gross structure of bark. R = Rhytidome, SP = Secondary phloem, ET = Expancion tissues, X = Xylem.

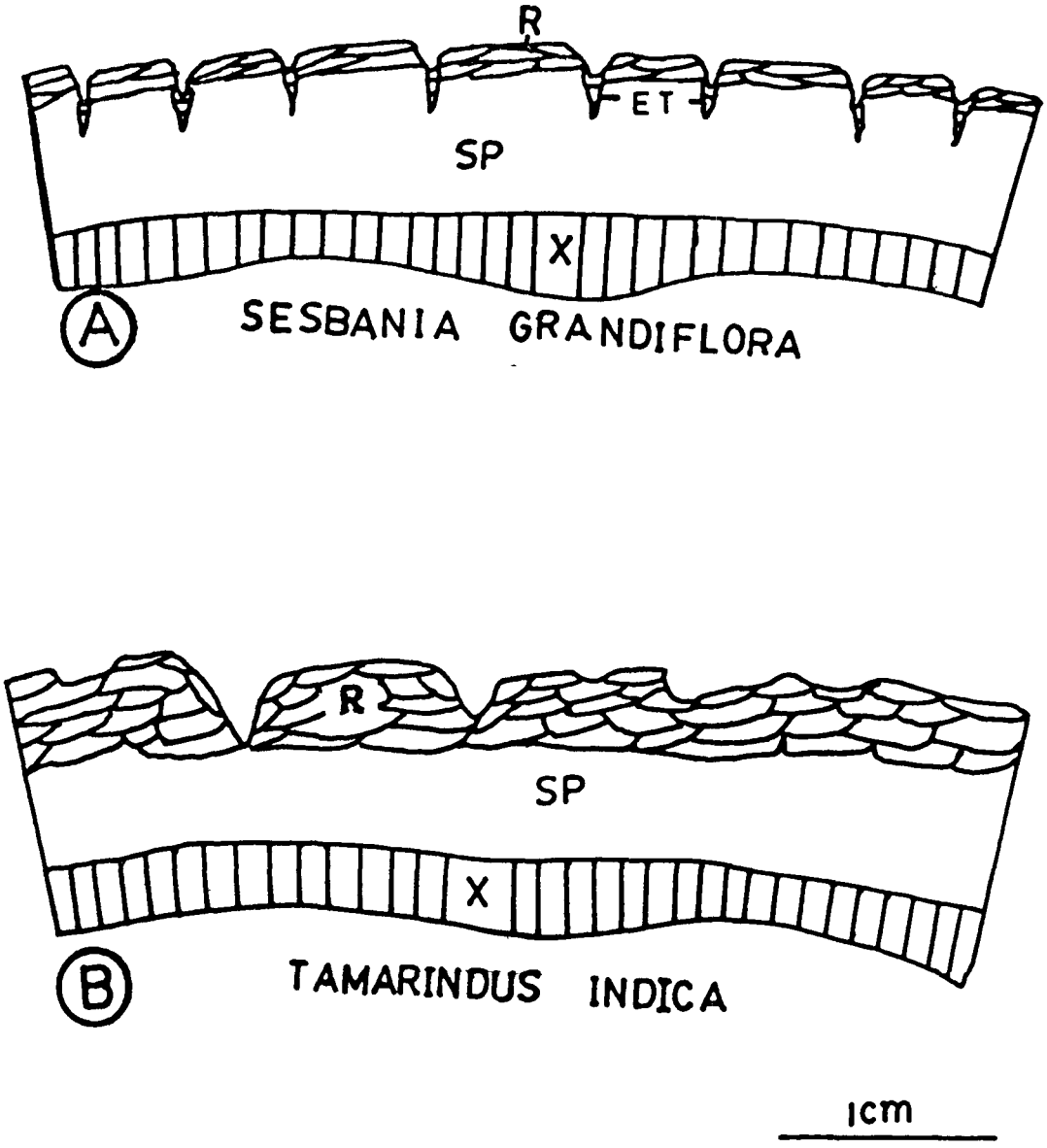
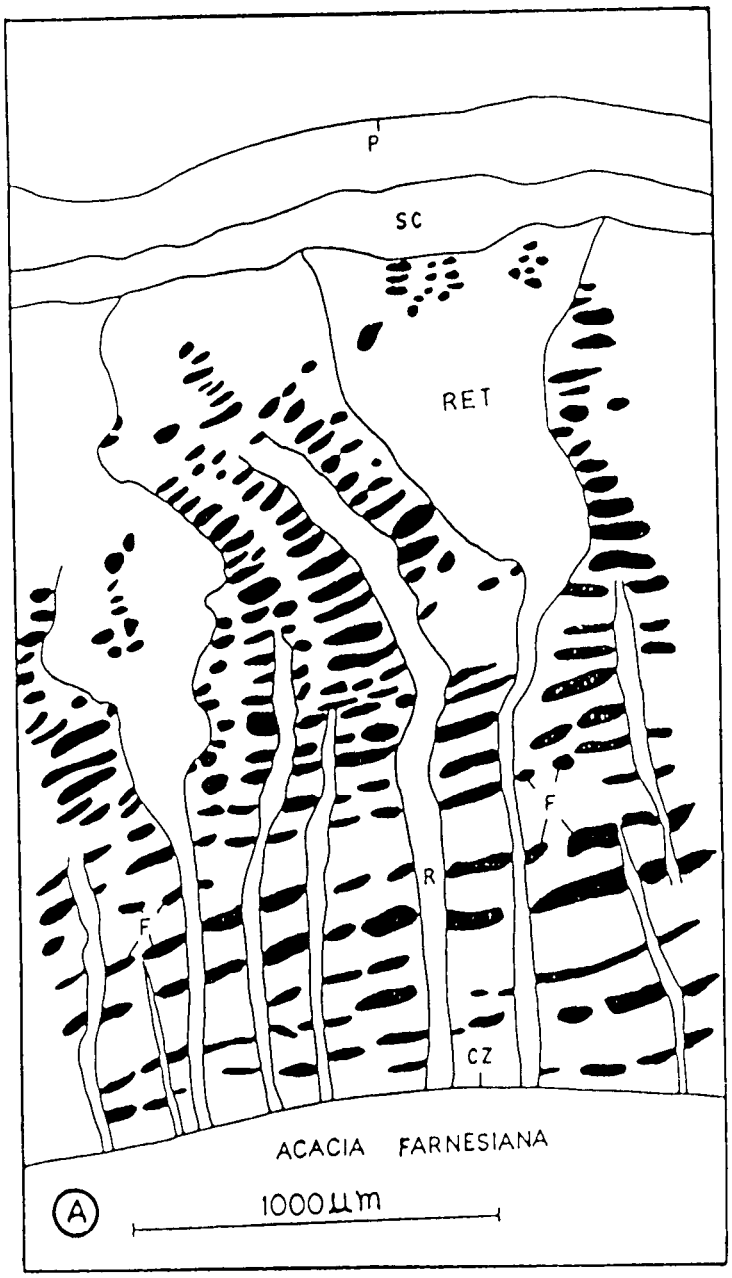


Fig. 10A-B. Slash surface showing fissuring pattern and gross structure of bark. R = Rytidome, SP = Secondary phloem, ET = Expansion tissues, X = Xylem.

Fig.11A-B Camera lucida diagram of the bark in transverse section showing the distribution pattern of fibre, ray,sclereid and the position of periderm. CZ = cambium zone, F = fibre groups, R = ray, RET = ray expansion tissue, SC = sclereid, P = periderm.


P
SC
RET
F
R
F
CZ
ACACIA FARNESIANA
A
1000 µm


RET
B
CASSIA FISTULA

Fig.11

Fig.12A-B Camera lucida diagram of the bark in transverse section showing the distribution pattern of fibre, ray,sclereid and the position of periderm. CZ = cambium zone, F = fibre groups, R = ray, RET = ray expansion tissue, SC = sclereid, P = periderm.

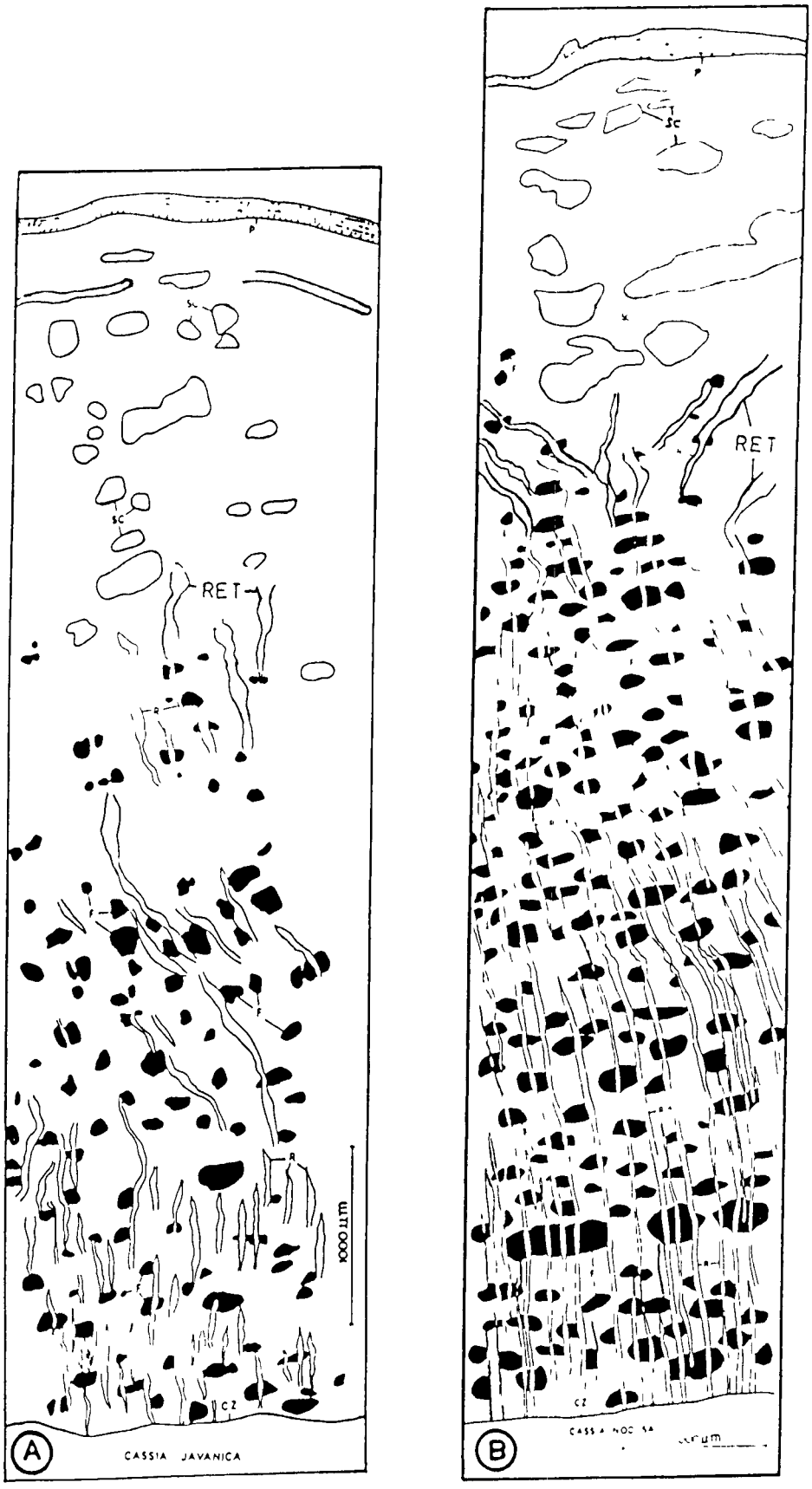


Fig.12

Fig. 13 A-B Camera lucida diagram of the bark in transverse section showing the distribution pattern of fibre, ray,sclereid and the position of periderm. CZ = cambium zone, F = fibre groups, R = ray, RET = ray expansion tissue, SC = sclereid, P = periderm.

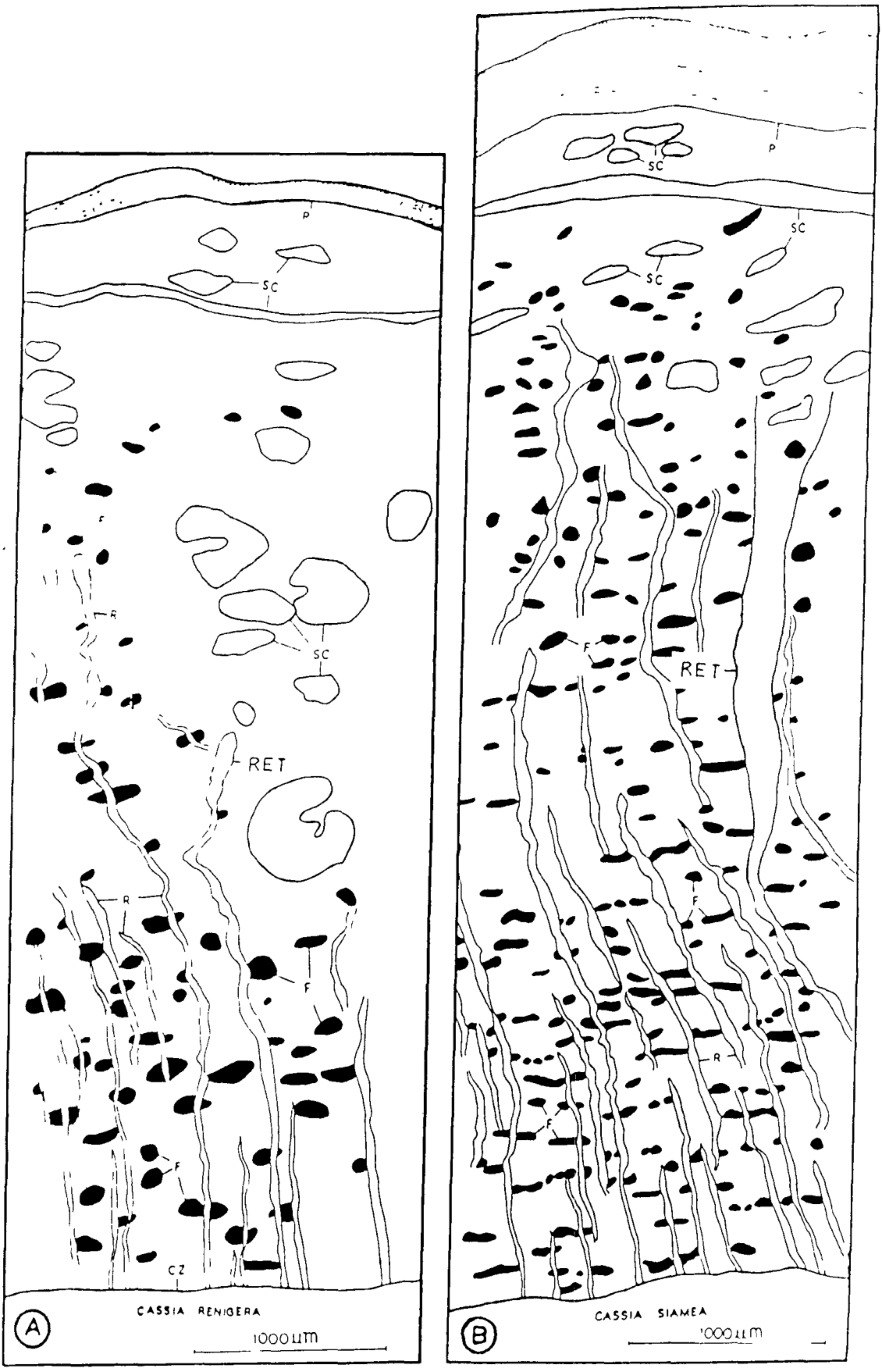

P
SC
SC
SC
RET
R
F
F
F
CZ
CASSIA RENIGERA
1000 µm
A
P
SC
SC
SC
RET
F
F
R
F
CASSIA SIAMEA
1000 µm
B

Fig.13

Fig.14A-B Camera lucida diagram of the bark in transverse section showing the distribution pattern of fibre, ray,sclereid and the position of periderm. CZ = cambium zone, F = fibre groups, R = ray, RET = ray expansion tissue, SC = sclereid, P = periderm.


P
SC
RET
F
R
F
R
CZ
A
DELONIX REGIA
1000 µm
RET
B
ERYTHRINA INDICA

Fig.14

Fig.15A-B Camera lucida diagram of the bark in transverse section showing the distribution pattern of fibre, ray,sclereid and the position of periderm. CZ = cambium zone, F = fibre groups, R = ray, RET = ray expansion tissue, SC = sclereid, P = periderm.

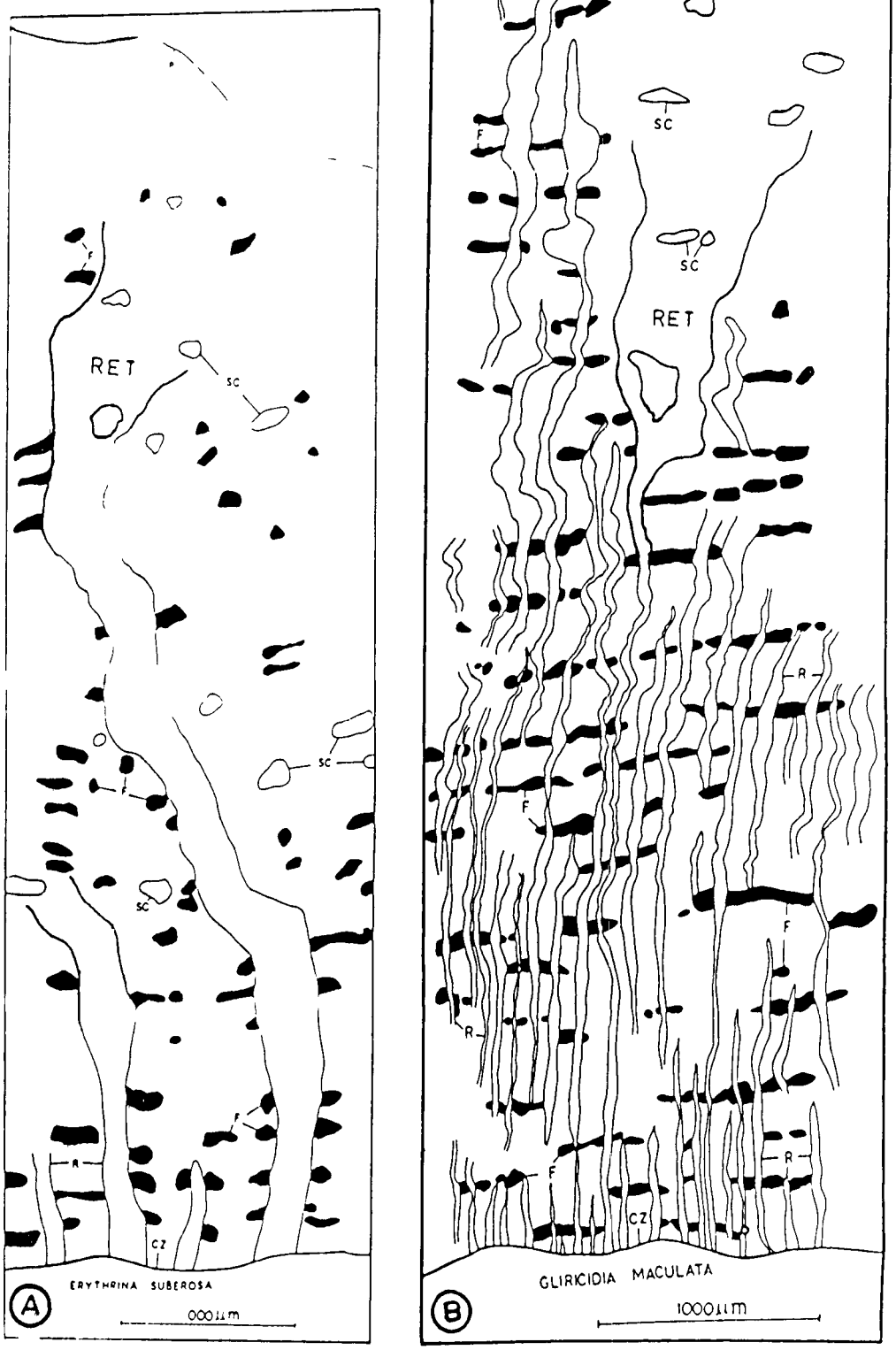
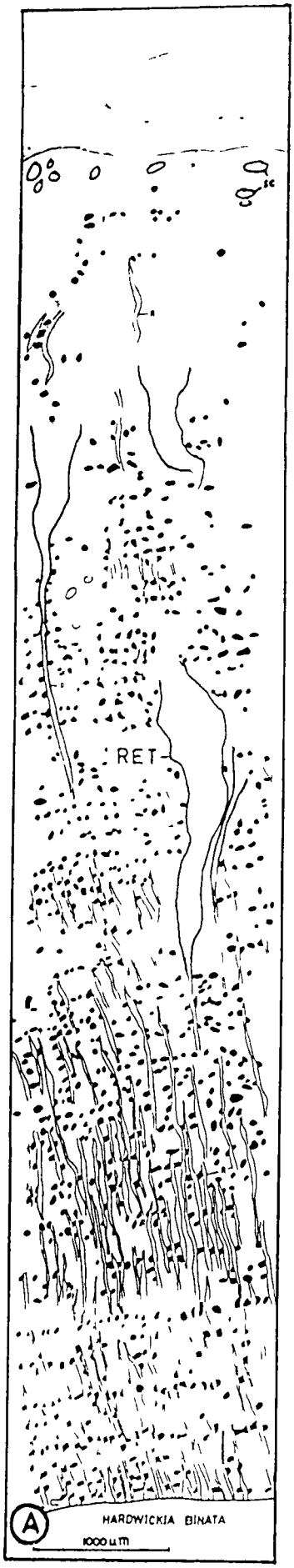

RET
SC
F
R
CZ
P
ERYTHRINA SUBEROSA
A
1000µm
GLIRICIDIA MACULATA
B
1000µm

Fig.15

Fig.16A-B Camera lucida diagram of the bark in transverse section showing the distribution pattern of fibre, ray,sclereid and the position of periderm. CZ = cambium zone, F = fibre groups, R = ray, RET = ray expansion tissue, SC = sclereid, P = periderm.


SC
RET
A
HARDWICKIA BINATA
1000 µm

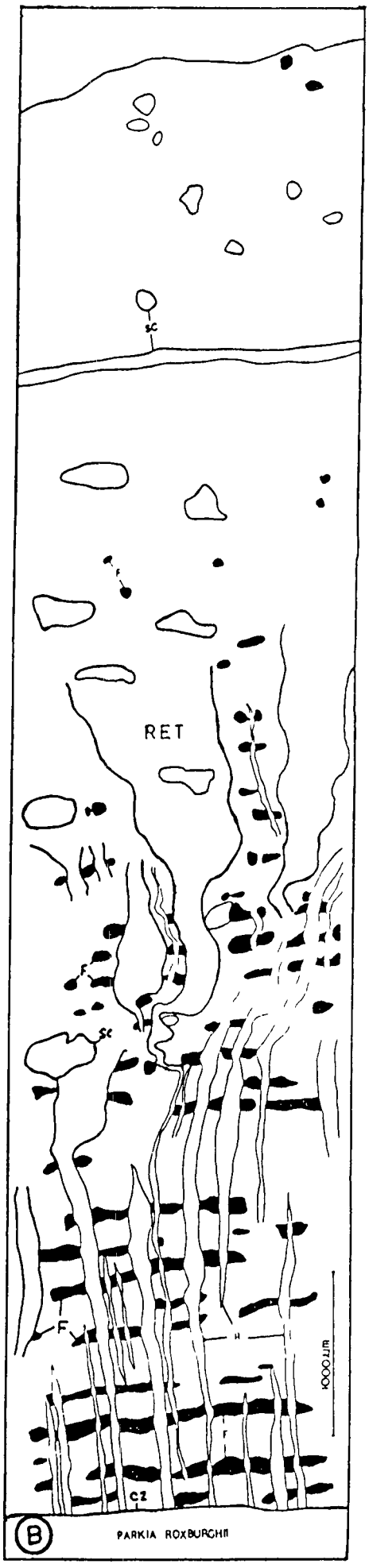

SC
RET
F
SC
F
H
F
1000 µm
CZ
B
PARKIA ROXBURGHII

Fig.16

Fig.17A-B Camera lucida diagram of the bark in transverse section showing the distribution pattern of fibre, ray,sclereid and the position of periderm. CZ = cambium zone, F = fibre groups, R = ray, RET = ray expansion tissue, SC = sclereid, P = periderm.

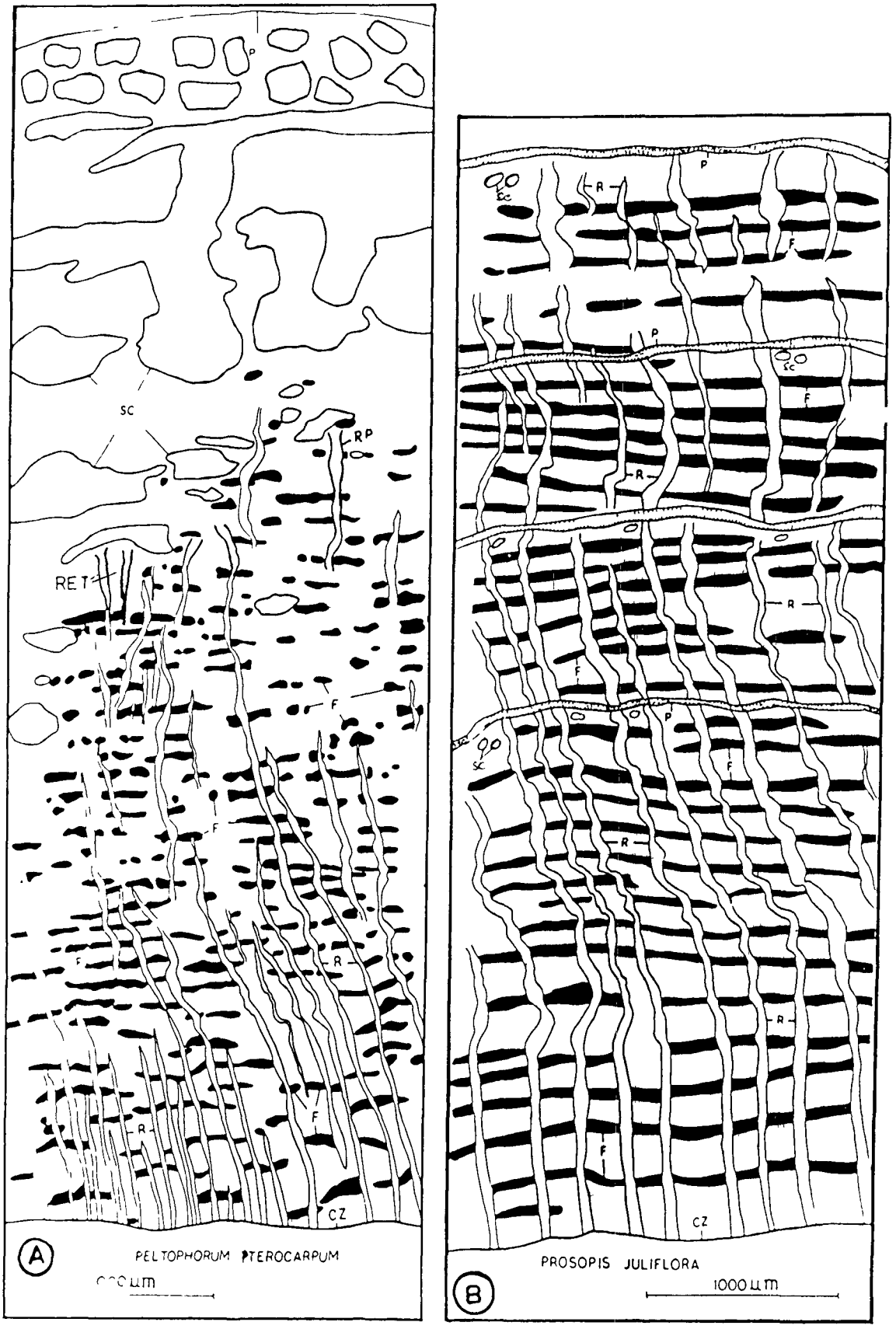

P
SC
RP
RET
F
R
CZ
A
PELTOPHORUM PTEROCARPUM
1000 µm
P
R
F
SC
CZ
B
PROSOPIS JULIFLORA
1000 µm

Fig.17

Fig.18A-C Camera lucida diagram of the bark in transverse section showing the distribution pattern of fibre, ray,sclereid and the position of periderm. CZ = cambium zone, F = fibre groups, R = ray, RET = ray expansion tissue, SC = sclereid, P = periderm.

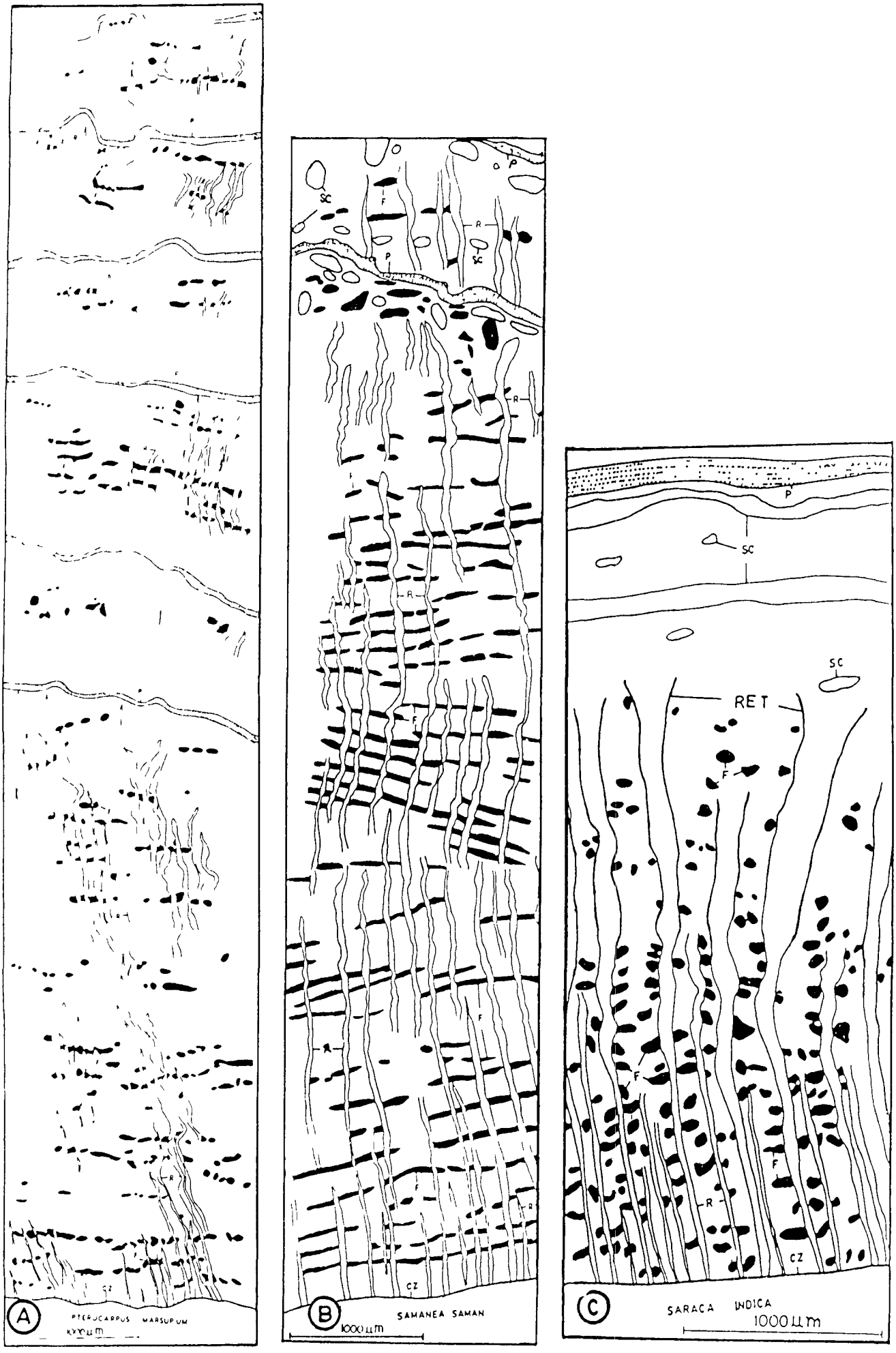

A
PTERUCARPUS MARSUPIUM
B
SAMANEA SAMAN
1000 µm
C
SARACA INDICA
1000 µm
SC
RET
P
F
R
CZ

Fig.18

Fig.19A-B Camera lucida diagram of the bark in transverse section showing the distribution pattern of fibre, ray,sclereid and the position of periderm. CZ = cambium zone, F = fibre groups, R = ray, RET = ray expansion tissue, SC = sclereid, P = periderm.

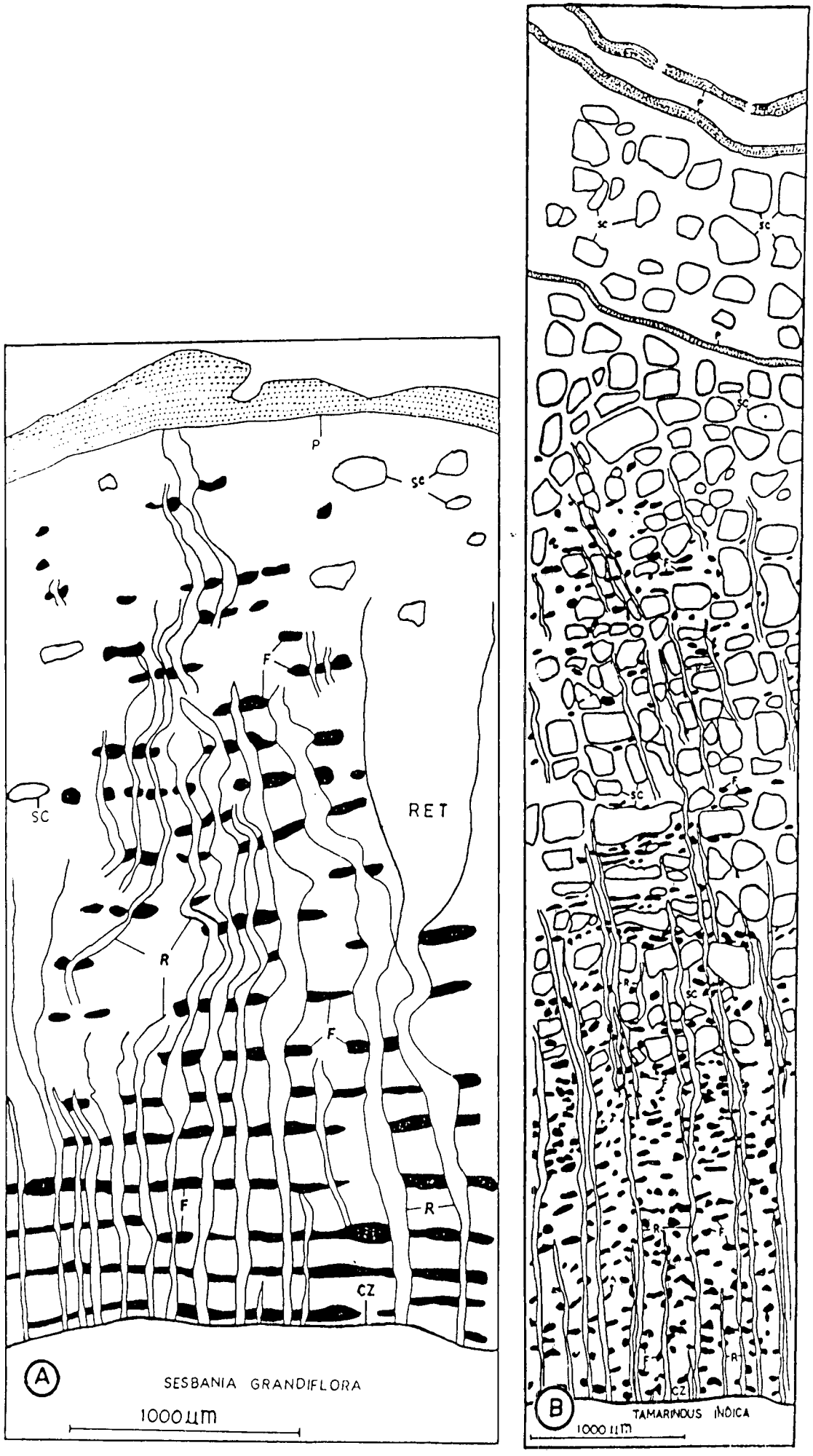

P
SC
F
RET
R
CZ
A
SESBANIA GRANDIFLORA
1000 µm
B
TAMARINDUS INDICA
1000 µm

Fig.19

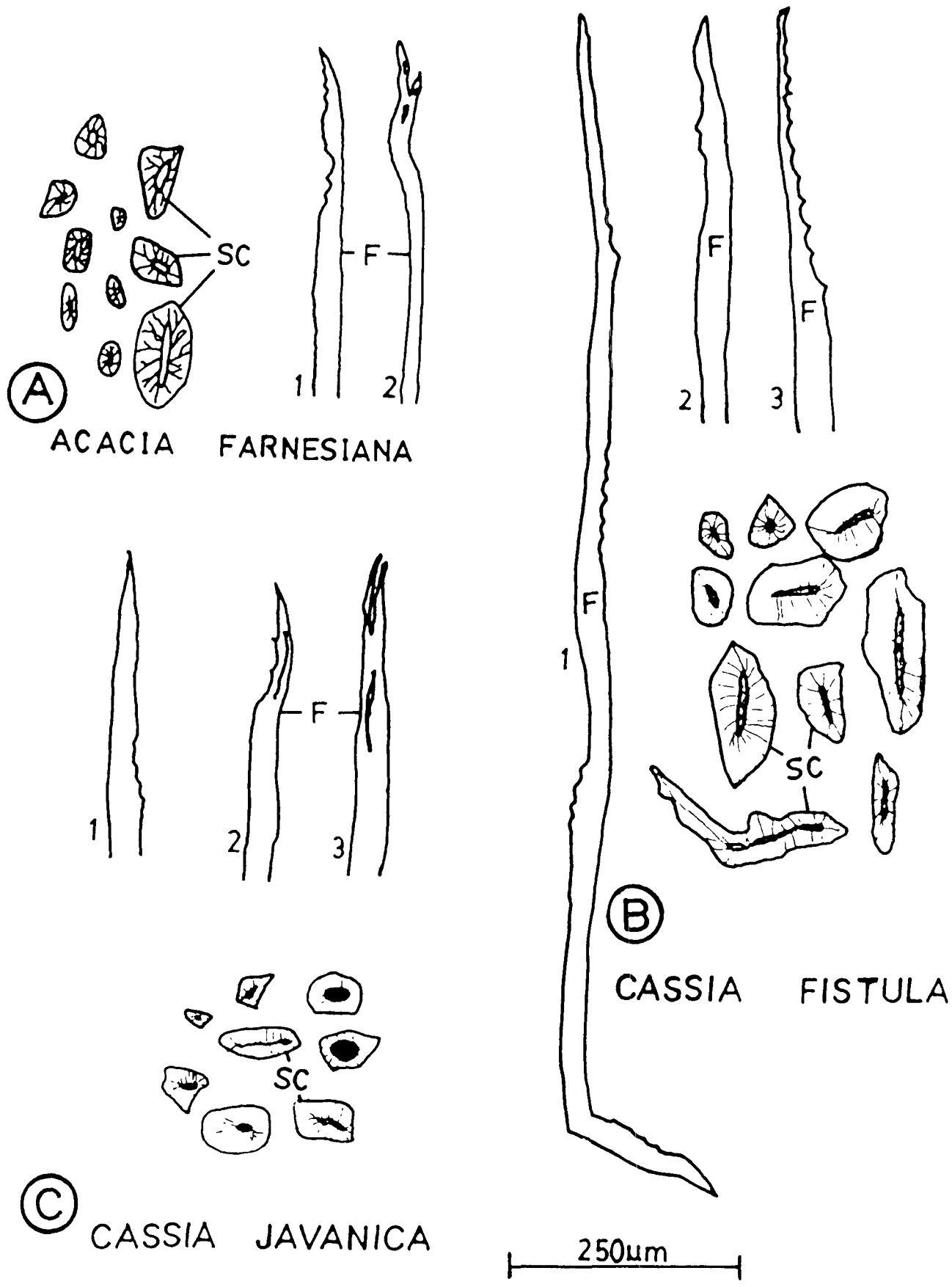


Fig. 20A-C. Camera lucida diagram showing types of sclereids and fibre apices. SC = Sclereids, F = Fibre, A.1-Serrate apices, 2-Forked apices, B.1-Serrate apices, 2 & 3-Dentate apices, C.1-Serrate apices, 2-Dentate apices, 3-Forked apices.

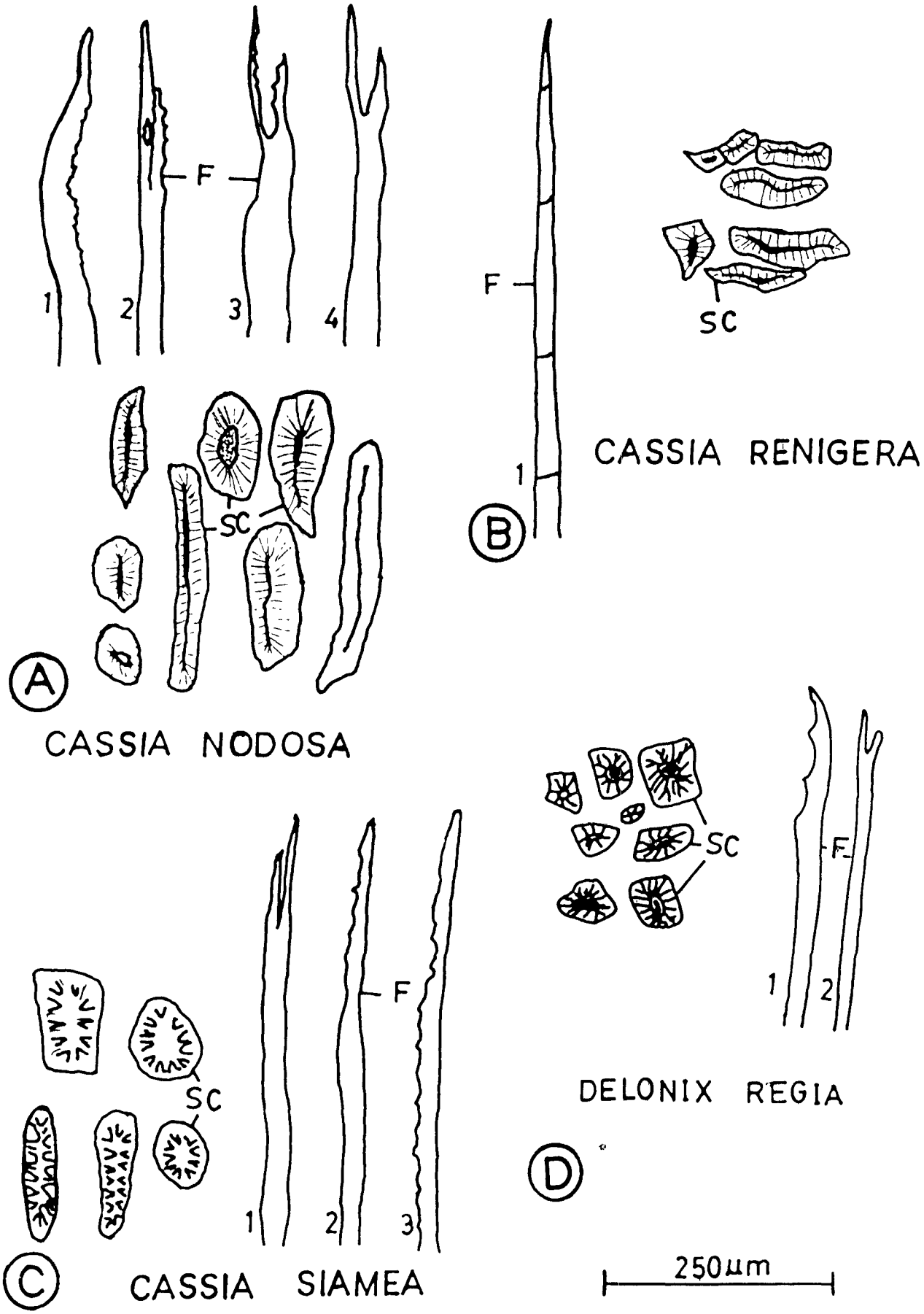


Fig. 21A-D. Camera lucida diagram showing types of sclereids and fibre apices. SC = Sclereids, F = Fibre, A.1-Serrate apices, 2 & 3 - Forked apices with serration, 4-Bifurcate apices, B.1-Septate fibre, C.1-Forked apices, 2 & 3 - Serrate apices, D.1-Dentate apices, 2-Forked apices.

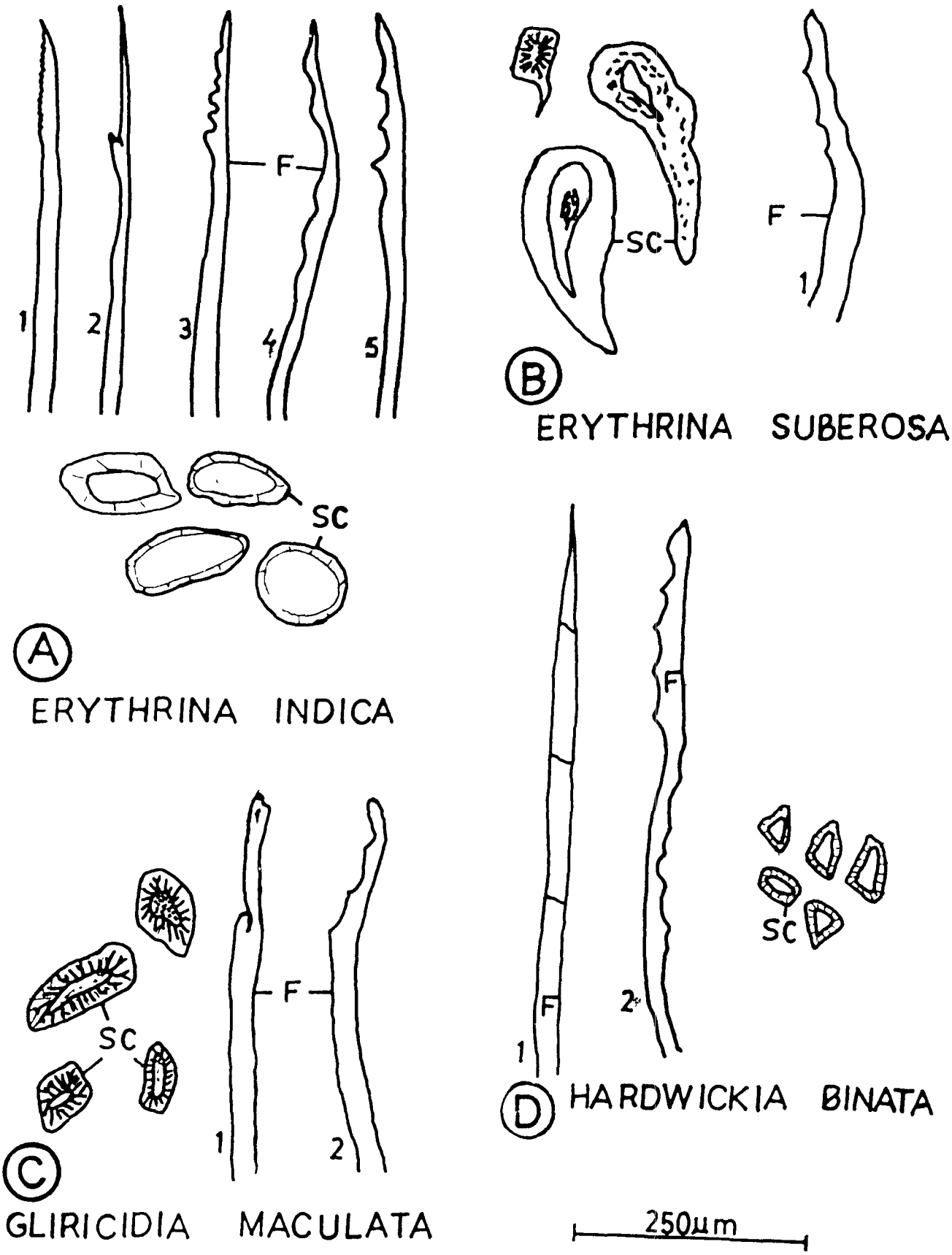


Fig. 22A-D. Camera lucida diagram showing types of sclereids and fibre apices. SC = Sclereids, F = Fibre, A.1-Serrate apices, 2-Forked apices, 3,4&5-Dentate apices, B.1-Dentate apices, C.1-Forked apices, 2-Dentate apices, D.1-Septate fibre, 2-Dentate fibre.

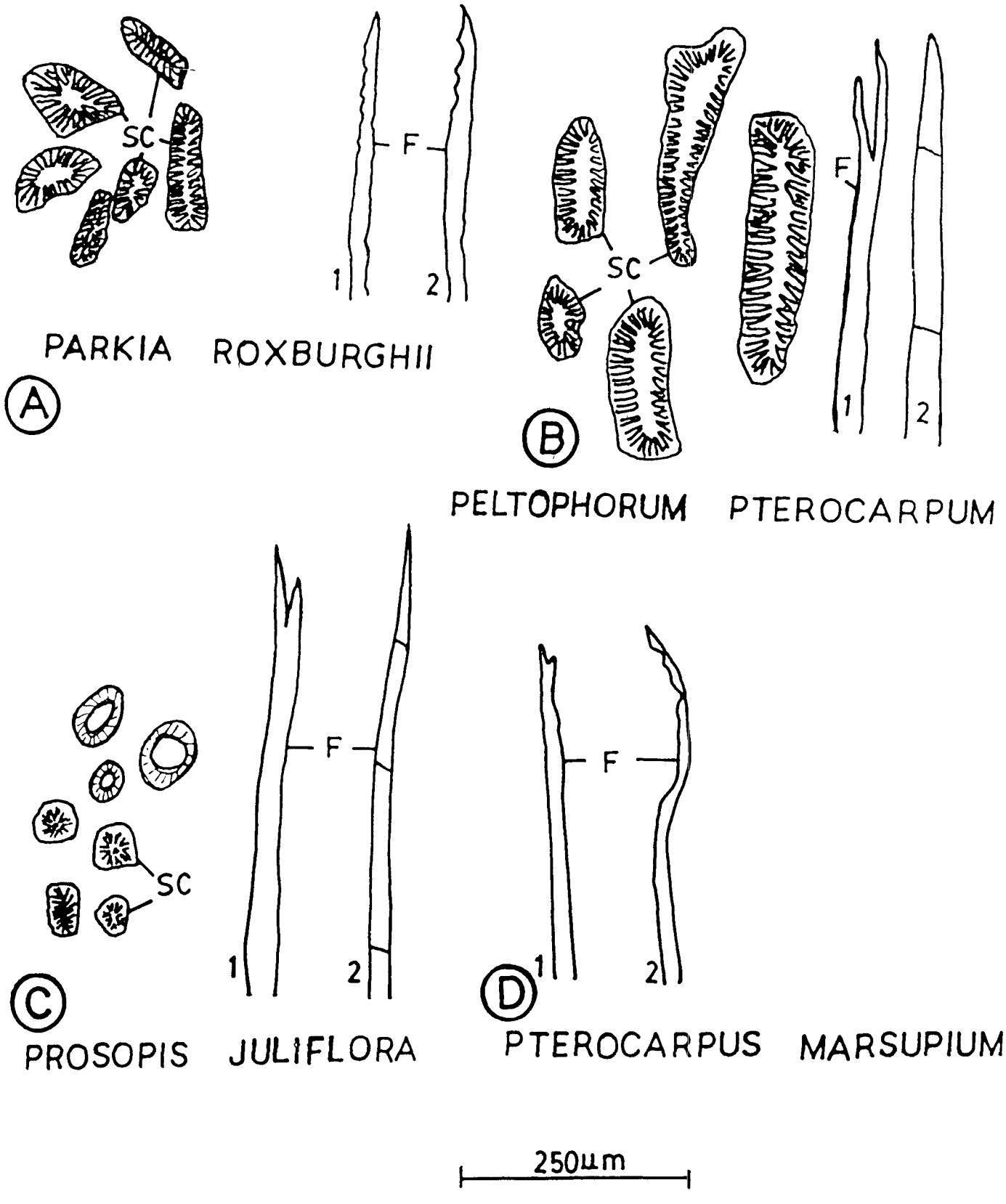


Fig. 23A-D. Camera lucida diagram showing types of sclereids and fibre apices. SC = Sclereids, F = Fibre, A.1 = Septate fibre, B.1 = Serrate apices, 2-Dentate apices, C.1 - Septate apices, D.1-Dentate apices.

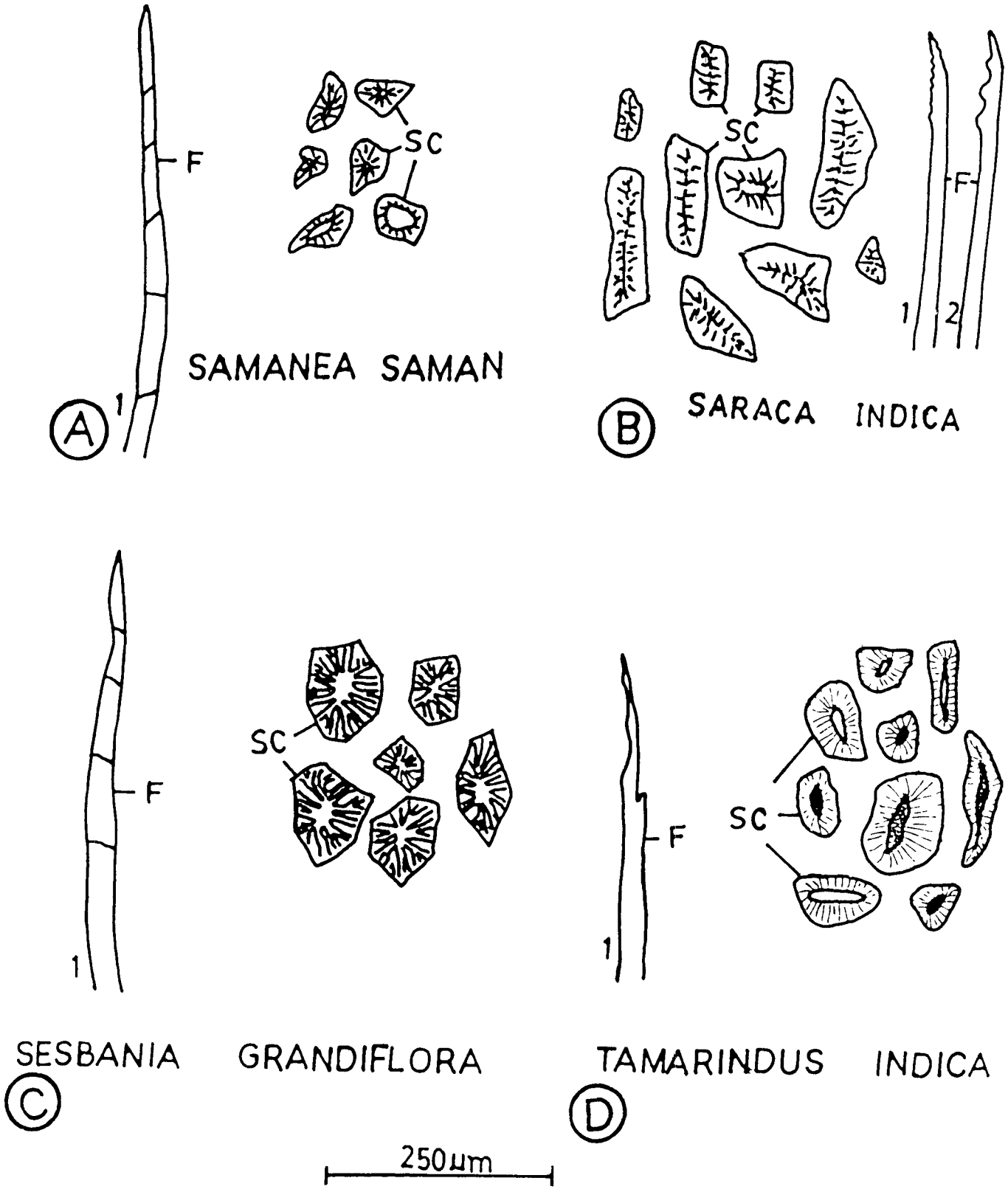


Fig. 24A-D. Camera lucida diagram showing types of sclereids and fibre apices. SC = Sclereids, F = Fibre. A.1 - Serrate apices, 2-Dentate apices, B.1 - Forked apices, 2-Septate fibre, C.1 - Forked apices, 2-Septate apices, D.1 - Forked apices, 2-Serrate apices.

DISCUSSION

Based on surface characteristics (Table - 14) the barks of selected cultivated leguminous trees are grouped under three categories:

1. Smooth or non-fissured (*Acacia farnesiana*, *Cassia javanica*, *C. nodosa*, *Delonix regia*, *Erythrina indica*, *Gliricidia maculata*, and *Saraca indica*).

2. Shallow-fissured (*Cassia siamea*, *Hardwickia binata*, *Parkia roxburghii*, *Sesbania grandiflora* and *Tamarindus indica*).

3. Deep-fissured (*Cassia fistula*, *Cassia renigera*, *Erythrina suberosa*, *Peltophorum pterocarpum*, *Prosopis juliflora*, *Pterocarpus marsupium* and *Samanea saman*).

The characteristics of bark such as colour, texture thickness of rhytidomes, types of fissured number and arrangement of periderm layers, extent of expansion tissue, presence, distribution and orientation of lenticels, the colour and behaviour of blaze and sloughing pattern do prove helpful in identification to a certain extent but not below the generic level in the leguminous trees studied as it was done by Whitmore (1962 a,b,c, and 1963) in *Dipterocarpaceae* and *Fagaceae* and Kumar (1969) in *Prosopis specigera*. Recently, Malychenko (1986) and Khan (1985) found the morphological characteristics of bark

as useful for the identification of Salix species, some leguminous trees of Madhya Pradesh (India) respectively. So far as identification upto species level is concerned, it has not been achieved in the present study, using only the surface features. The work on the anatomy of the secondary phloem in Winteriaceae (Esau and Cheadle 1984), the microscopic features of the bark of Salix species (Malychenko 1986) and anatomy of secondary phloem of genus Inga (Trochenbrodt and Parameswaran 1986) have successfully been utilized for taxonomic purposes.

On the basis of their Micromorphology, the barks under study are divisible into three zones, the inner comprising of conducting phloem and the middle made up of non-conducting secondary phloem and the outer represented by islands of hard and dead crust, the rhytidome (Whitmore, 1962a, b; 1963; Esau, 1964; Iqbal and Ghouse, 1982).

In the present investigation, the bark of Cassia fistula, C. javanica, C. siamea, Delonix regia, Erythrina indica, Gliricidia maculata and Saraca indica has been noted to possess only a single superficial periderm while in others occurrence of multiple periderm has been observed. As such the secondary phloem in the former occupies the major portion of the bark while in the latter, the outer dead crust of the rhytidome constitute the bulk of the bark. The secondary phloem in all

cases is further divisible into conducting and non-conducting parts. The conducting phloem comprises of sieve-tube members with one or more associated companion cells, axial parenchyma, fibres arranged in different patterns and rays. The non-conducting part, on the other hand, exhibits no functional seive-tube elements and companion cells but occasionally has a few crushed or obliterated seive tubes structures, expansion of ray parenchyma or axial parenchyma or sclereids.

Microscopic analysis of the secondary phloem of the investigated species has revealed considerable variation in size, amount and pattern of distribution of various components (Table 15, 16). Similar observation, on the variation pattern of bark components has been recorded in the past by various workers (Barghoorn, 1940; Esau et al., 1953; Cheadle and Esau 1964, Geiger et al., 1969; Evans et al., 1970; Grange and Peel, 1975; Ghouse and Hashmi, 1976; Ghouse and Hashmi, 1977; Hashmi, 1977; Khan, 1977; Ghouse and Iqbal, 1978; Ghouse and Hashmi, 1978; Ahmad et al., 1979; Ghouse et al., 1979; Ghouse and Iqbal, 1979; Khan et al., 1979; Khan, 1979; Khan, 1980; Khan et al., 1982; Iqbal and Ghouse, 1982; Khan and Khan, 1983; Siddiqui,1983, Khan,1985; Khan & Mahmooduzzafar,1986;Malychenko, 1988; Ahmad & Khalimullah,1988,1989).

The secondary phloem of Acacia farnesiana, C. fistula, C. nodosa, C. renigera, Delonix regia, Peltophorum pterocarpum, Parkia roxburghii, Prosopis juliflora, Samanea saman and Tamarindus indica is characterised with certain primitive

features such as long sieve-tube elements with compound and obliquely oriented sieve plates, arranged in a non-stratified order. On the other hand, Erythrina indica, E. suberosa, Gliricidia maculata, Pterocarpus marsupium and Sesbania grandiflora exhibited phylogenetically advanced features like short, sieve-tube elements with transverse or nearly truncate end walls with simple sieve plates arranged in stratified order (Cheadle and Whitford, 1941; Cheadle, 1948; Cheadle and Uhl, 1948; Esau et al. 1953; Esau, 1965; Zahur, 1959; Fahn, 1982; Khan, 1985; Outer, 1986).

The sieve-tube elements are considered as the principal channels for translocation of photosynthates ever since their discovery by Hartig (1837). Since early thirties, investigations were carried out to find out the proportion of actual area of translocation in the phloem. Crafts (1931 and 1933) found that only 17% and 23% of the phloem happen to be active in cucurbit stems and potato stolons respectively. He, therefore, postulated that only one fifth of the phloem to be engaged in the process of translocation. On the other hand, Münch (1930 and 1943) estimated two-third of the phloem as active in some tree trunks. Later using improved techniques Geiger et al. (1969) and Evans et al., (1970) obtained about 30% of pholem as active in sugar beet petiols and wheat peduncles respectively. However, Lawton and Canny (1970) and Canny

(1973) considered the two third factor of Münch to be more appropriate for adoption for the purpose of calculations in specific mass transfer studies than Craft's one-fifth value. The present study reveals that the investigated species fall in the range of 4.13% to 54.63% (Table - 15) and therefore, do not fall under crafts category or that of Münch referred above.

The present work and the studies carried out in the past (Lawton, 1972, 1976; Grange and Peel, 1975; Ghouse and Hashmi, 1976; Ghouse et al.. 1976; Ghouse and Iqbal, 1978; Ghouse and Jamal, 1979; Ahmad et al. 1979; Iqbal, 1979; Khan, 1979; Khan et al, 1982; Khan, 1984; Milburn and Kallarackal, 1984; Ahmad and Kalimullah, 1988) indicate that active area in the conducting phloem remains more or less constant in a species i.e., it is species specific.

The phloem fibres form the major component of mechanical tissue of the bark and form the most characteristics constituent of the secondary phloem as far as the taxonomic traits are concerned. Their amount and distribution pattern in transection of the bark has been compared in table 16. The distribution pattern of phloic fibres is so regular and characteristic of the species as to provide a useful clue for identification. Similar observations have been made on the barks of number of taxa by others too (Kundu, 1942; Holdheide,1951; Chattaway, 1953; 1955a,b,c,d,e, 1959; Chang, 1954a,b; Zahur,

1959; Santos, 1960; Bamber, 1962; and Outer, 1967). Recently, attempts have been made by the Aligarh School of Plant Anatomy, to exploit the distribution pattern as well as the relative proportion of phloem fibres to identify the isolated bak samples of pharmaceutical importance otherwise identical in appearence with some success (Ghouse and Yunus, 1974b; Ghouse and Hashmi, 1979; Ghouse and Jamal, 1978; Ghouse et al, 1976, 1979; Khan et al, 1979; Khan et al., 1982; Khan and Khan, 1983; Khan, 1984, Khan and Mahmooduzzafar, 1986).

The phloem fibres in the presently investigated species showed that they are mostly long narrow elements with long tapering ends with lignified walls enclosing narrow lumen which often become obliterated. In all the investigated species, the fibres are non-septate except Cassia renigera, Hardwickia binata, Peltophorum pterocarpum, Prosopis juliflora, Sesbania grandiflora and Samanea saman, as in the majority of dicotylodons. The distribution pattern of the phloem fibres has been found to be regular in species studied (Table 16). They are in fascicles arranged in regular tangential bands in Acacia farnesiana, Parkia roxburghii, Prosopis juliflora, Samanea saman and Sesbania grandiflora (Fig. 25,a,b,c, and Fig.26b,c,), in fascicles of varying size arranged in discontinuous tangential bands in Cassia nodosa C. siamea, Erythrina suberosa, Gliricidia maculata,

Hardwickia binata, Peltophorum pterocarpum and Pterocarpus marsupium (Fig. 26a, Fig. 27b,c, Fig. 28b,d, Fig. 29a,c)and scattered as isolated elements or in small or big groups in Cassia fistula, C. javanica, C. renigera, Delonix regia, Erythina indica, Saraca indica and Tamarindus indica (Fig. 27a, Fig. 28a,c, Fig. 29b, Fig. 30a,b,c,). The amount of fibres in the conducting phloem varies greatly from 5.96% to as high as 22.47% (Table 16). The phloem fibres are of various shape and size in the different species (Fig. 20, 21, 22, 23, 24). Generally, they are long with tapering ends which exhibit various types of structural manifestations such as forking, apical or sub-apical branchings serrations or dentations and even depression at one or both the ends. This is apparently due to the apical intrusive growth which appears to be a universal factor among phloem fibres, as has been observed earlier in other species (Kundu, 1942; Kundu and Sen, 1961; Liese and Parameswaran, 1972; Ghouse and Sabir, 1974; Ghouse and Yunus, 1974a; Siddiqui et al., 1976; Ghouse and Hashmi, 1977, 1978; Ghouse and Iqbal, 1979; Khan, 1980; Khan and Khan, 1983; Khan, 1984; Khan 1985; Kalimullah et al.,1989). The present findings on apical structural modification of phloem fibres are in agreement with those reported by Ghouse and Yunus (1975) in some Dalbergia species, Ghouse and Hashmi (1977, 1978) in some

evergreen and deciduous Indian tropical trees, Ghouse and Iqbal (1978) in Acacia and Prosopis and Khan (1985) in some forest leguminous trees of Madhya Pradesh. The intrusive growth in Thuja occidentalis is considerably more in downward direction (Bannan, 1956) than in the upward while in Boehmaria nivea, it is more in the upward direction than otherwise (Kundu and Sen, 1961). However, in the presently investigated species, the apical elongation has been found to be bipolar.

The phloic rays are exclusively homogeneous in all the species excepting Hardwickia binata a feature considered to be phylogenetically advanced by a number of workers in the past (Barghoorn, 1940; Esau, 1960; Carlquist, 1961;Shimaji, 1962). In width, the phloic rays show a variation of uniseriate to triseriate types in Cassia fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Hardwickia binata, Peltophorum pterocarpum, Pterocarpus marsupium, Saraca indica, Sesbania grandiflora and Tamarindus indica, while in Delonix regia, Gliricidia maculata, Parkia roxburghii, Prosopis juliflora and Samanea saman, the rays are invariably multiseriate. However, the multiseriate rays are more common in Acacia farnesiana, Erythrina indica and E. suberosa than in the other species studied.

The sclereids constitute about 1.50 to 41.62% of non-conducting phloem in different investigated species except Pterocarpus marsupium in which sclereids are totally absent. The average of sclereids length varied from 52 µm to 184 µm while the width varied from 31 to 61 µm (Table 16). Distribution pattern of sclereids happened to be in regular tangential band in Acacia farnesiana, while in Cassia fistual, C. javanica, C. renigera, C. siamea, Parkia roxburghii and Saraca indica, they are in one or two tangential bands in addition to their presence in small or in big groups. In Tamarindus indica the sclereids occur in big groups which in turn tend to form regular bands. In Cassia nodosa, Delonix regia, Erythrina indica, E. suberosa, Gliricidia maculata, Hardwickia binata, Peltophorum pterocarpum, Prosopis juliflora, Samanea saman and Sesbania grandiflora the sclereids are found in scattered groups (Fig. 31-36).

The arrangement of axial and radial systems in the investigated species fall under three main categories. In Acacia farnesiana, C. fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Delonix regia, Hardwickia binata, Parkia roxburghii, Prosopis juliflora, Samanea saman, Saraca indica and Tamarindus indica the axial and radial system are non-stratified, whereas in Erythrina indica and E. suberosa the axial system is stratified and radial system non-stratified.

However, in case of Peltophorum pterocarpum, the axial system is non-stratified and the radial stratified. But in case of Gliricidia maculata,Pterocarpus marsupium and Sesbania grandiflora both the axial and radial system are stratified. The stratified arrangement is considered to be an advanced feature according to standards established by Zahur (1959) and Outer (1986).

To accommodate the tangential strain and stress exerted by the increasing number of cambial derivatives year after year, the outer dead part, the rhytidome splits into fissures which are eroded further by weathering process to slough, however, maintaining the characteristics texture and colour of the bark. On the contrary, the inner bark coups with this pressure through ray expansion and parenchyma proliferation. In Acacia farnesiana, Cassia fistula, C. javanica, C. nodosa,C. renigera,C.siamea, Delonx regia, Erythrina indica, E. suberosa, Gliricidia maculata, Hardwickia binata, Parkia roxburghii, Peltophorum pterocarpum, Pterocarpus marsupium, Saraca indica and Sesbania grandiflora the ray expansion tissue is prominent enough to be visible with the unaided eye except Prosopis juliflora, Samanea saman and Tamarindus indica. Schneider (1955) ascribed the formation of expansion tissue to the activity of meristem developed inside the rays i.e. the dilation meristem. The rays expansion seems to be due to tangential

stretching and anticlinal division of ray cells(Present study). This tissue has been referred to in the literature by various names such as 'dilation tissue'(Schneider,1955), 'phloem expansion' (Whitmore,1962a & 1963)and 'ray expansion'(Kumar,1969). But Iqbal and Ghouse(1982), who also termed it as 'ray expansion tissue'. I prefere to call it ray expansion tissue, i.e. a tissue developed through the enlargement and division of ray cells. Degree of ray expansion, sclereids and parenchyma proliferation varies with species.Similar findings are made out in the present investigation.In Cassia fistula,C.renigera, Erythrina suberosa, Hardwickia binata,Peltophorum pterocarpum,Prosopis juliflora, Ptercarpus marsupium, Samanea saman, Sesbania grandiflora and Tamarindus indica for instance,this is quite sufficient to cope with growing girth of the stem and, therefore, greatly alleviates the need of fissuring which is, however, inevitable in species where the amount of expansion and proliferation fails to compensate for the strain caused by the inner derivates.

Thus, variation of such features as fissuring,periderm layers, ray expansion, distribution of fibre, sclereid, and sieve-tube characters are collectively suggestive, albeit individually indecisive, for identification purposes. As the bark construction forms an aid to identification, this together with other morphological features, should be weighed for systematic consideration Accordingly, a dichotomous key is prepared in the following manner for the identification of the species studied.(See pp.148-49).

Comparison of some macroscopic and microscopic feature used in the preparation of dichotomous key:

Macroscopic features:

I. Colour of Bark: The colour of bark is studies by Whitmore (1962a) in Dipterocarpaceae and found that it differs in different species. In the present investigation also, the barks are grouped on the bais of colour. The bark is black in colour in Cassia renigera, Sesbania grandiflora, brown in Acacia farnesiana, Cassia javanica, C. siamea, C. nodosa, Delonix regia, Erythrina indica, Hardwickia binata, Parkia roxburghii, Peltophorum pterocarpum, Prosopis juliflora, Pterocarpus marsupium, Samanea saman, Saraca indica, Tamarindus indica, Creamy in Erythrina indica and greyish green in Cassia fistula and Gliricidia maculata.

II. Fissuring: Based on surface characteristics, the barks of leguminous trees studies are categorised into deep or shallow fissured and entire (Iqbal and Ghouse, 1982). Whitmore (1962a) has also categorised the bark surface of Dipeterocarpaceae into seven groups viz., smooth surface, dippled, shallow and deep fissured, scaly, surface rotten and laminate and used them as a characters for taxonomic purpose. In the present study, using the surface features, the different species are categorized under three main groups i.e. (1) non-fissured or smooth type as in Acacia farnesiana, Cassia javanica, C. nodosa, Delonix regia,

Erythrina indica, Gliricidia maculata and Saraca indica (ii) shallow fissured as in Cassia siamea, Hardwickia binata, Parkia roxburghii, Sesbania grandiflora and Tamarindus indica and (iii) Deep-fissured in Cassia fistula, C. renigera, Erythrina suberosa, Peltophorum pterocarpum, Prosopis juliflora, Pterocarpus marsupium & Samanea saman.

III. Sloughing of bark:

The bark peels off in the form of powder/scales/strips/papery (Whitmore 1962a). The bark sloughs off in powder form or in minute scales of various shapes and sizes in Acacia farnesiana, Cassia javanica, Delonix regia, Gliricidia maculata and Saraca indica. In Cassia fistula, C. nodosa, C. siamea, Erythrina suberosa, Parkia roxburghii, Peltophorum pterocarpum, Pterocarpus marsupium and Sesbania grandiflora, the bark peels off in the form of small scales, while in Cassia renigera and Tamarindus indica it occurs in the form of large scales of varies shapes and sizes. However, in Prosopis juliflora and Samanea saman the bark peels off in form of long vertical strips and in Erythrina indica and Hardwickia binata it peels off in the form of papery flakes or layers.

IV. Bark thickness;

The thickness of bark varies from species to species.

The bark of some species is thick and in others it is thin. On this basis the investigated species are categorised into two groups but it is not useful for the identification purpose of the species especially when the bark pieces are dry. The species which have thick barks are Cassia fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Erythrina indica, E. suberosa, Gliricidia maculata, Hardwickia binata, Parkia roxburghii, Peltophorum pterocarpum, Prosopis juliflora, Pterocarpus marsupium, Samanea saman, Sesbania grandiflora, Tamarindus indica and those having thin bark are Acacia farneriana, Delonix regia and Saraca indica.

V. Rhytidome thickness:

The thickness of rhytidome differ in different species (Whitmore 1962a, Iqbal and Ghouse 1982). In the present study the rhytidome is thick in some species and comparatively thin in others. However, the thickness of rhytidome is not used in the key for the identification of the species. On the basis of thickness of rhytidome the different investigated species are categorised into two main groups. The rhytidome is thick in Cassia fistula, C. renigera, Erythrina suberosa, Hardwickia binata, Parkia roxburghii, Peltophorum pterocapum, Prosopis juliflora, Pterocarpus marsupium, Samanea saman, Sesbania grandiflora, and Tamarindus indica and thin

in Acacia farnesiana, Cassia javanica, C. nodosa, C. siamea, Delonix regia, Erythrina indica, Gliricidia maculata and Saraca indica.

VI. Rhytidome:

The arrangement and the number of periderms varis species to species (Whitmore 1962a, Iqbal and Ghouse 1982, and Khan 1985). In some species periderm is single and superficial and in some the periderm is multiple and deep. On the basis of periderm number the investigated species is categorised into two main groups. This feature is successfully employed by Khan (1985) in his dichotomouskey for the identification. The periderm is single and superficial in Acacia farnesiana, Cassia javanica, C. nodosa, C. siamea, Delonix regia, Erythrina indica, Gliricidia maculata and Saraca indica and multiple and deep in Cassia fistula, C. renigera, Erythrina suberosa, Hardwickia binata, Parkia roxburghii, Peltophorum pterocarpum, Prosopis juliflora, Pterocarpus marsupium, Samanea saman, Sesbania grandiflora and Tamarindus indica.

VII. Expansion tissues:

The ray expansion tissues is studied in the bark of *Dipterocarpaceae and in* Acacia *and* Prosopis *specis by* Whitmore (1962a), Iqbal and Ghouse (1982) respectively. Khan (1985)

has also observed the ray expansion tissue in the bark of some leguminous trees of Bhopal, Madhya Pradesh with the help of hand lens. He has used this feature in a dichotomous key for the identification of species. In some species the ray expansion tissue is absent while in others it is very prominent. The ray expansion tissues are narrow and not visible under band lens in Prosopis juliflora, Samanea saman and Tamarindus indica and it is clearly visible to naked eye or under a hand lens in Acacia farnesiana, Cassia fistula, C. javanica, C. nodosa, Cassia renigera, C. siamea, Delonix regia, Erythrina indica, E. suberosa, Gliricidia maculata, Hardwickia binata, Parkia roxburghii, Peltophorum pterocarpum, Pterocarpus marsupium, Saraca indica & Sesbania grandiflora.

Microscopic features:

VIII. Selereids:

Selereids constitute an additional mechanical tissue system in the barks of a number of hardwood species. The shape and size and distribution pattern of sclereids differ in different species (Rao, 1951; Arzee, 1953; Inamdar and Gangadhara, 1974; Ghouse et al. 1977). Review of literature shows that sclereids are not commonly used in the past for taxonomic purpose. The distribution pattern of sclereids is so peculiar that it is extensively used in the present investigation and employed in the dichotomous key for the

purpose of identification of the species. On the basis of distribution pattern of sclereids, the investigated species were categorised into different groups. Sacher (1954) and Srivastava (1963) are reported that sclereids does not contain in either functional or non-functional phloem in Pinus species. Similar result is noted in Pterocarpus marsupium. The other investigated species contain sclereid in groups/patches forming varying shape and size or in regular tangential bands.

The sclereids are scattered in small groups/patches in Cassia javanica, Erythrina suberosa, Gliricidia maculata, Hardwickia binata Prosopis juliflora, Samanea saman and Sesbania grandiflora and they occur in big patches in Cassia fistula, C. nodosa, Delonix regia, Erythrina indica and Peltophorum pterocarpum. They are in one or more regular tangential bands in Acacia farnesiana, Cassia renigera, C. siamea, Parkia roxburghii, Saraca indica and Tarmarindus indica.

IX. Fibre:

The fibres form a major mechanical component of secondary phloem. The distribution pattern of fibres varies species to species. Thus, the distribution is used for identification purposes by a large number of worker in the past (Zahur 1959,

Ghouse and Yunus 1974b; Ghouse and Hashmi 1979, Ghouse et al 1979, Khan et al. 1979, Iqbal and Ghouse 1982, khan, 1985, Khan and Mahmooduzzafar, 1986, Malychenko, 1988). On the basis of distribution of fibres the investigated species are categorised into different groups. The fibres occur in parallel rows forming regular tangential bands in Acacia farnesiana, Parkia roxburghii, Prosopis juliflora, Samanea saman and Sesbania grandiflora, while they are in irregular tangential bands in C. nodosa, C. siamea, Erythrina suberosa, Gliricidia maculata, Hardwickia binata, Peltophorum pterocarpum and Pterocarpus marsupium is irregular. However, in Cassia fistula,C. javanica, C. renigera, Delonix regia, Erythrina indica, Saraca indica and Tamarindus indica they are scattered in groups/or in patches of varying shape and size.

X. Axial and Radial System:

Stratification of sieve-tube members and rays varies species to species. On the basis of stratification of axial and radial systems, the investigated species are categorised into different groups. The sieve tube members are stratified in Erythrina indica, and E. suberosa, while in Gliricidia maculata, Pterocarpus marsupium and Sesbania grandiflora both the sieve-tube members as well as the rays are stratified. However,in Peltophorum pterocorpum the rays are stratified.In

the remaining twelve out of the 19 species, the phloem is non-statified.

According to Bailey (1923), startified cambium occurrs only in structurally advanced dictyledons. The sieve tube members are remarkably short and show truncated or almost transverse end walls with simple perforation. Such features are generally accepted as phylogenetically advance (Zahur 1959, Outer 1986).

XI. Ray:

The width and depth as well as the frequency of ray differ widely (Ghouse and Yunus 1974c; Ghouse and Iqbal 1975, Ghouse et al., 1976, Ghouse and Hashmi, 1977). On the basis of ray width and depth as well as its frequency the investigated species are categorised into several distinct groups which are widely used in the dichotomous key for the identification of the species.

The ray width varies from uni to multiseriate in the investigated species. The rays are mostly narrow (1-3 seriate) in all the investigated species except Acacia farnesiana, Erythrina indica and E. suberosa in which the rays are multiseriate and broad. Like the width, the ray height also varies to a considerable extent. The ray height indicates

that they could be classified into short (1-10 cells), midium (11-20) and all (21 and above) categories. The rays are short in Cassia fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Gliricidia maculata, Hardwickia binata, Pterocarpus marsupium, Samanea saman and Sesbania grandiflora, medium (11-20 cells) in Delonix regia, Parkia roxburghii, Peltophorum pterocarpum, Prosopis juliflora, Saraca indica and Tamarindus indica and tall (21 and above) in Acacia farnesiana, Erythrina indica and E. suberosa.

The phloem rays are mostly homogeneous having only procumbent cells in Acacia farneriana, Cassia fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Delonix regia, Erythrina indica, E. suberosa, Gliricidia maculata, Parkia roxburghii, Peltophorum pterocarpum, Prosopis juliflora, Pterocarpus marsupium, Samanea saman, Saraca indica, Sesbania grandiflora and Tamarindus indica except Hardwickia binata in which they are homogeneous and heterogeneous.

They are frequency differ widely in different species. In Cassia fistula, C. siamea, Gliricidia maculata, Hardwickia binata, Peltophorum pterocarpum, Pterocarpus marsupium, Samanea saman and Tamarindus indica the ray frequency is more than $50/mm^2$, while in the rest it is less than $50/mm^2$ area.

XII. Secretory Cells:

The secretory cells, as well as secretory cavities and canals are used for diagnostic purposes in taxonomic work (Metcalfe and Chalk 1950). Venkaiah (1988) is also studied the gum duct in the Ailanthus excelsa. In the investigated species i.e. Delonix regia and Pterocarpus marsupium possess gum ducts which form an important feature for the classification of the species.

A dichotomous key for the identification of some leguminous trees of Aligarh (Uttar Pradesh) and Bhopal (Madhya Pradesh).

1.	Sclereids absent	*Pterocarpus marsupium*
2.	Sclereids present	2
	2. Sclereids in regular tangential bands	3
	2. Sclereids not in bands (scattered)	9
3.	Slcereid bands only one	4
3.	Sclereid bands more than one	8
	4. Fibre in bands	5
	4. Fibre not in bands	7
5.	Fibre in regular tangential bands	6
5.	Fibre not in regular tangential bands	*Cassia siamea*
	6. Rays are mostly broad	*Acacia farnesiana*
	6. Rays are not mostly broad	*Parkia roxburghii*
7.	Ray frequency high (> 50 rays/mm^2)	*Cassia fistula*
7.	Ray frequency not high (< 50 rays/mm^2)	*Cassia renigera*
	8. Sclereids bands more than two	*Tamarindus indica*
	8. Sclereids bands not more than two	*Saraca indica*
9.	Fibre in bands	10
9.	Fibre not in bands	17
	10. Sieve tube stratified	11
	10. Sieve tube non-stratified	13
11.	Fibre in regular bands	*Sesbania grandiflora*
11.	Fibre in irregular bands	12

12. Radial system stratified — *Gliricidia maculata*

12. Radial system non-stratified — *Erythrina suberosa*

13. Fibre in regular tangential bands — 14

13. Fibre in irregular tangential bands — 15

14. Rays mostly short (1-10 cells) — *Samanea saman*

14. Rays mostly medium(11-20 cells) — *Prosopis juliflora*

15. Radial system stratified — *Peltophorum pterocarpum*

15. Radial system non-stratified — 16

16. Homogeneous and heterogeneous rays present — *Hardwickia binata*

16. Only homogeneous rays present — *Cassia nodosa*

17. Radial system non-stratified — 18

17. Radial system stratified — *Erythrina indica*

18. Gum duct present — *Delonix regia*

18. Gum duct absent — *Cassia javanica*

Comparative data on the macroscopic and microscopic bark features of selected leguminous trees

	Af	Cf	Cs	Cn	Cr	Cs	Dr	El	Es	Gm	Hb	Pr	Pp	Pj	Pm	Ss	Sl	Sg	Tl
A. Macroscopic features:																			
I. Colour of bark:																			
1. Brown	+	-	+	+	-	+	+	+	-	-	+	+	+	+	+	+	+	-	+
2. Black	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	+	-
3. Creamy	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
4. Grayish green	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
II. Fissure - Non-fissured	+	-	+	+	-	-	+	+	-	+	-	-	-	-	-	-	+	-	-
6. Shallow-fissured	-	-	-	-	-	+	-	-	-	-	+	+	-	-	-	-	-	+	+
7. Deep-fissured	-	+	-	-	+	-	-	-	+	-	-	-	+	+	+	+	-	-	-
III. Sloughing of bark:																			
8. Powder/minute scales	+	-	+	-	-	-	+	-	-	+	-	-	-	-	-	-	+	-	-
9. Small scales	-	+	-	+	-	+	-	-	+	-	-	+	+	-	+	-	-	+	-
10. Long flakes/scales	-	-		-	-	+	-	-	-	-	-	-	-	+	-	+	-	-	+
11. Form of papery flakes	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-
IV. Bark thickness:																			
12. Thick (more than 0.5cm)	-	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	-	+	+
13. Thin (less than 0.5 cm)	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-
V. Rhytidome:																			
14. Periderm single superficial	+	-	+	+	-	+	+	+	-	+	-	-	-	-	-	-	+	-	-
15. Periderm multiple and deep	-	+	-	-	+	-	-	-	+	-	+	+	+	+	+	+	-	+	+
16. Thick (more than 0.2cm)	-	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	+	+
17. Thin (less than 0.2 cm)	+	-	+	+	-	+	+	+	-	+	-	-	-	-	-	-	+	-	-

	Af	Cf	Cl	Cn	Cr	Cs	Dr	El	Es	Gm	Hb	Pr	Pf	Pj	Pm	Ss	Sl	Sq	Tl
VI. Expansion tissue:																			
18. Ray expansion tissue broad wedge shapes & visible under hand lens	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	+	-
19. Ray expansion tissue narrow & not visible under hand lens	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	+
B. Microscopic features:																			
VII. Sclereids:																			
20. Sclereids present	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+
21. Sclereids more than one band	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+
22. Sclereids in a single band	+	+	-	-	+	+	-	-	-	-	-	+	-	-	-	-	-	-	-
23. Sclereids in groups/ small patches	-	-	+	-	-	+	-	-	+	+	+	-	-	+	-	+	-	+	-
24. Sclereids in big patches	-	+	-	+	+	-	+	+	-	-	-	+	+	-	-	-	-	-	-
VIII. Fibre:																			
25. Fibres in groups but scattered	-	+	+	-	+	-	+	+	-	-	-	-	-	-	-	-	+	-	+
26. Fibres in regular continuous bands	+	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+	-	+	-
27. Fibres in discontinuous & irregular bands	-	-	-	+	-	+	-	-	+	+	+	-	+	-	+	-	-	-	-
IX. Axial & radial system:																			
28. Sieve-tube in stratified order	-	-	-	-	-	-	-	+	+	+	-	-	-	-	+	-	-	+	-
29. Rays in stratified order	-	-	-	-	-	-	-	-	-	+	-	-	+	-	+	-	-	+	-
30. Sieve-tube & rays both in stratified order	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	+	-

X. Ray: Hight:																				
31. Rays mostly(more than 50%)short(1-10 cells)	-	+	+	+	+	+	-	-	-	+	+	-	-	-	+	+	-	+	-	
32. Rays mostly(more than 50%)medium(11-20cells)	-	-	-	-	-	-	+	-	-	-	-	+	+	+	-	-	+	-	+	
33. Rays mostly(more than 50%)tall(21-above)	+	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	
Width:																				
34. Rays mostly broad (more than 50%)	+	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	
35. Rays mostly narrow (more than 50%) (1-3 scriate)	-	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	
36. Homogeneous rays present	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	
37. Homogeneous & heterogeneous rays present	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	
Frequency:																				
38. Ray frequency high (> 50rays/mm^2)	-	+	-	-	-	+	-	-	-	+	+	-	+	-	+	+	-	-	+	
39. Ray frequency low (lesser than 50 rays/ mm^2)	+	-	+	+	+	-	+	+	+	-	-	+	-	+	-	-	+	+	-	
Ducts:																				
40. Gum duct present	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	

Note: (+) : Present, (-):Absent.

Af = Acacia farnesiana, Cf = Cassia fistula, Cj = Cassia javanica, Cn = Cassia nodosa, Cr = Cassia renigera, Cs = Cassia siamea, Dr = Delonix regia, Ei = Erythrina indica, Es = Erythrina,suberosa, Gm=Gliricidia maculata, Hb = Hardwickia binata, Pr = Parkia roxburghii, Pp = Peltophorum pterocarpum, Pj = Prosopis juliflora, Pm = Pterocarpus marsupium, Ss = Samanea saman, Si = Saraca indica, Sq = Sesbania grandiflora, Ti = Tamarindus indica.

Table - 14

Comparison of surface and slash features

Name of the species	Circumference (Cm)	Bole appearance	Surface configuration	Expansion tissue	Periderm	Sloughing
1	2	3	4	5	6	7
Acacia farnesiana	35	Smooth with round eye marks, brown	No fissuring	Fusiform + wedge shaped	Periderm single superficial	Minute scales (2x1 mm)/powder
Cassia fistula	70	Deep-fissured,	V-section	Long broad wedge	Rhytidome thick, periderm parallel to cambium for some distance then deviate outwards.	Chunky small thick scale (few Cm^2)
C javanica	80	Nearly smooth, greyish brown	No fissuring	Fusiform + wedge shaped	Periderm single superficial	Minute scale (2x1 mm^2)/powder.
C. nodosa	116	Nearly smooth, blackish brown	No fissuring	Fusiform + large broad wedge shaped	Periderm single superficial	Small scales (7x4 mm^2).
C renigera	106	Deep-fissured, blackish	Irregular fissuring	Narrow wedge below fissure	Rhytidome thick periderm parallel to combium for some distance then deviate outwards.	In the form of thick flakes (20x20 mm^2).
C. siamea	80	Shallow-fissured, light grey	V-section fissuring	Fusiform + wide wedge shaped	Periderm single superficial	Small irregular fragments(30x20mm^2)
Delonix regia	79	Smooth,reddish brown	No fissuring	Wide wedge shaped	Periderm single superficial	Minute scales (1x0.5 mm^2)/powder
Erythrina indica	72	Smooth,yellowish or greyish grey	No fissuring	Fusiform + wide wedge shaped	Periderm single superficial	In thin papery flakes.
E suberosa	108	Deep-fissured creamy	V-section fissuring	Wide wedge mostly below fissure	Rhytidome thick periderm parallel to cambium with thick cork.	In the form of corky scales (60x40 mm^2)with thickness of 20 mm
Gliricidia maculata	67	Smooth,pale green or greyish green	No fissuring	Fusiform - narrow wedge shaped	Periderm single superficial	Minutes scales (3x2 mm^2)/powder

Hardwickia binata	64	Shallow - fissured, dark grey	V-section fissuring	Long and narrow wedge shaped	Rhytidome slightly thick, periderm layers regular.	In the form (10x10 mm) of papery flakes.
Parkia roxburghii	108	Shallow-fissured, greyish brown or blackish	V-section fissuring	Long and wide wedge shaped	Rhytidome thin, periderm parallel to cambium for short distance then deviate outwards.	Small scales (12x8 mm^2).
Peltophorum pterocarpum	152	Shallow-fissured, greyish brown to blackish	V-section fissuring	Narrow wedge shaped	Rhytidome thick, periderm parallel to cambium for some distance then deviate outwards	Small scale (12 x 8 mm^2).
Prosopis juliflora	72	Deep-fissured, greyish brown	Compund fissuring	Not visible	Rhytidome thick, periderm parallel to each other.	In the form of long vertical strips (90x20 mm^2)
Pterocarpus marsupium	102	Deep-fissured, whitish grey or light brown	Irregular section fissuring	Long and narrow wedge shape below fissure	Rhytidome thick, periderm parallel to each other.	Thick scales (50x20 mm^2)
Samanea saman	128	Deep-fissured, dark grey	V-section fissuring	Not visible	Rhytidome thick, periderm parallel to cambium for some distance then deviate outwards.	Hard thick flakes (120x40 mm^2)
Saraca indica	55	Entire, with warty surface, dark brown	No fissuring	Fusiform + narrow wedge shaped	Periderm single superficial	Minute scale (3x1 mm^2)/powder
Sesbania grandiflora	42	Shallow-fissured black	V-section fissuring	Narrow wedge shaped	Rhytidome slightly thick, periderm run parallel to cambium for some distance then deviate outwards.	In small scales (7x2 mm^2)
Tamarindus indica	360	Shallow-fissured slate grey or light brown	V-section fissuring	Not visible	Rhytidome thick, periderm layer irregular	Large scales (70x30 mm^2)

*Figure in parantheses indicate the mean surface area of scale in round figure.

Surface area = length x width = (l x w).

Table - 15

Comparative study of sieve-tube elements

Name of the species	L/W (m)	Arrangement	Sieve plate	End wall	Amount(%)	Description
Acacia farnesiana	290/32	Non-stratified	Compound	Incline	29.04	In groups (4-9 cells) to form tangential bands (4).
Cassia fistula	322/25	-do-	-do-	-do-	14.82	Scattered in groups (3-9 cells)
C. javanica	364/33	-do-	-do-	-do-	11.78	In groups(4-13 cells) to from irregular tangential bands.
C. nodosa	259/29	-do-	-do-	-do-	15.13	Scattered in small groups (2-4 cells) isolated.
C. renigera	270/40	-do-	-do-	-do-	17.40	Scattered in groups(2-9 cells)/isolated
C. siamea	353/32	-do-	-do-	-do-	7.19	Scattered in groups(2-9 cells)/ isolated.
Delonix regia	445/38	-do-	-do-	-do-	54.63	Scattered in groups(4-8 cells)
Erythrina indica	245/35	Stratified	Simple	Tangential	27.49	Scattered in groups(3-5 cells)
E suberosa	353/36	-do-	-do-	-do-	20.37	In big groups(12-60 cells)form regular tangential bands (4).
Gliricidia maculata	180/22	-do-	-do-	-do-	15.98	In groups(4-13 cells)form discontinuous tangential bands.
Hardwickia binata	252/28	Non-stratified	Compound	Incline	5.81	Scattered in small groups(2-5 cells)/ isolated
Parkia roxburghii	328/34	-do-	-do-	-do-	10.62	In groups(5-12 cells)form regular tangential bands (3).
Peltophorum pterocarpum	351/28	-do-	-do-	-do-	8.36	Scattered in small groups(2-5 cells)/ isolated.
Prosopis juliflora	225/19	-do-	-do-	-do-	26.78	In small groups(2-6 cells) form regular tangential bands (3).
Pterocarpus marsupium	190/18	Stratified	Simple	Tangential	13.62	In groups (9-15 cells) form irregular tangential bands (3).
Samanea saman	184/38	Non-stratified	Compound	Incline	28 87	Scattered in groups (6-20 cells)
Ziziphus indica	381/36	Non-stratified	Compound	Incline	40.79	Scattered in groups (5-12 cells)
Sesbania grandiflora	195/32	Stratified	Simple	Tangential	15 89	In groups (2-6 cells) form regular tangential bands (4)
Tamarindus indica	240/27	Non-stratified	Compound	Incline	16.99	Scattered in small groups (2-5 cells)/ isolated

Table - 16

Comparative study of Schlerenchyma

Name of the species	Fibres			Sclereids		
	L/W(μm)	Amount(%)	Distribution	L/W(μm)	Amount(%)	Distribution
Acacia farnesiana	1199/21	18.39	Regular tangential band	55/35	9.11	In a tangential band
Cassia fistula	840/20	13.59	In big groups, Scattered	104/49	11.95	Mostly in small patches, Scattered with a tangential band.
C. Javanica	651/20	11.69	In big groups, Scattered	123/36	9.74	Mostly in small patches, Scattered
C. nodosa	638/23	22.47	In big groups, irregular tangential bands	114/42	16.48	In big patches, Scattered
C. renigera	593/20	12.56	In big groups, Scattered	74/34	13.57	In big patches with a tangential bands
C. siamea	995/20	13.35	In big fascicles, irregular tangential bands	124/31	13.18	In small patches with a tangential band.
Delonix regia	1742/18	7.06	Small groups/isolated, Scattered	91/37	27.50	In big patches, Scattered.
Erythrina indica	1599/18	5.96	Big fascicles, Scattered.	98/42	2.32	In big patches, scattered.
E. suberosa	1281/31	8.45	In big groups, irregular tangential bands.	184/61	3.04	Small patches, Scattered.
Gliricidia maculata	771/12	10.09	In big fascicles, irregular tangential bands.	52/47	3.34	Small patches, Scattered.
Hardwickia binata	1549/12	10.34	Small fascicles, irregular tangential bands.	62/47	1.50	Small patches, Scattered.
Parkia roxburghii	1111/15	10.04	Regular tangential bands	63/38	4.12	In big and small patches with a tangential bands.
Peltophorum pterocarpum	851/16	14.23	Big fascicles, irregular tangential bands.	170/42	26.38	In big patches, Scattered.
Prosopis juliflora	978/21	12.30	Regular tangential bands	97/33	2.05	Small patches, Scattered.
Pterocarpus marsupium	1237/28	10.94	Small fascicles irregular tangential bands.	-	-	-
Samanea saman	1055/18	13.63	Regular tangential bands	54/36	10.55	Small patches, Scattered.
Saraca indica	1083/16	16.27	Small groups, Scattered	88/43	19.20	Small groups with two tangential bands.
Sesbania grandiflora	1202/20	17.48	Regular tangential bands	70/49	2.65	Small groups, Scattered.
Tamarindus indica	901/16	13.26	Small groups/isolated, Scattered	70/38	41.62	In big patches to form multi regular tangential bands.

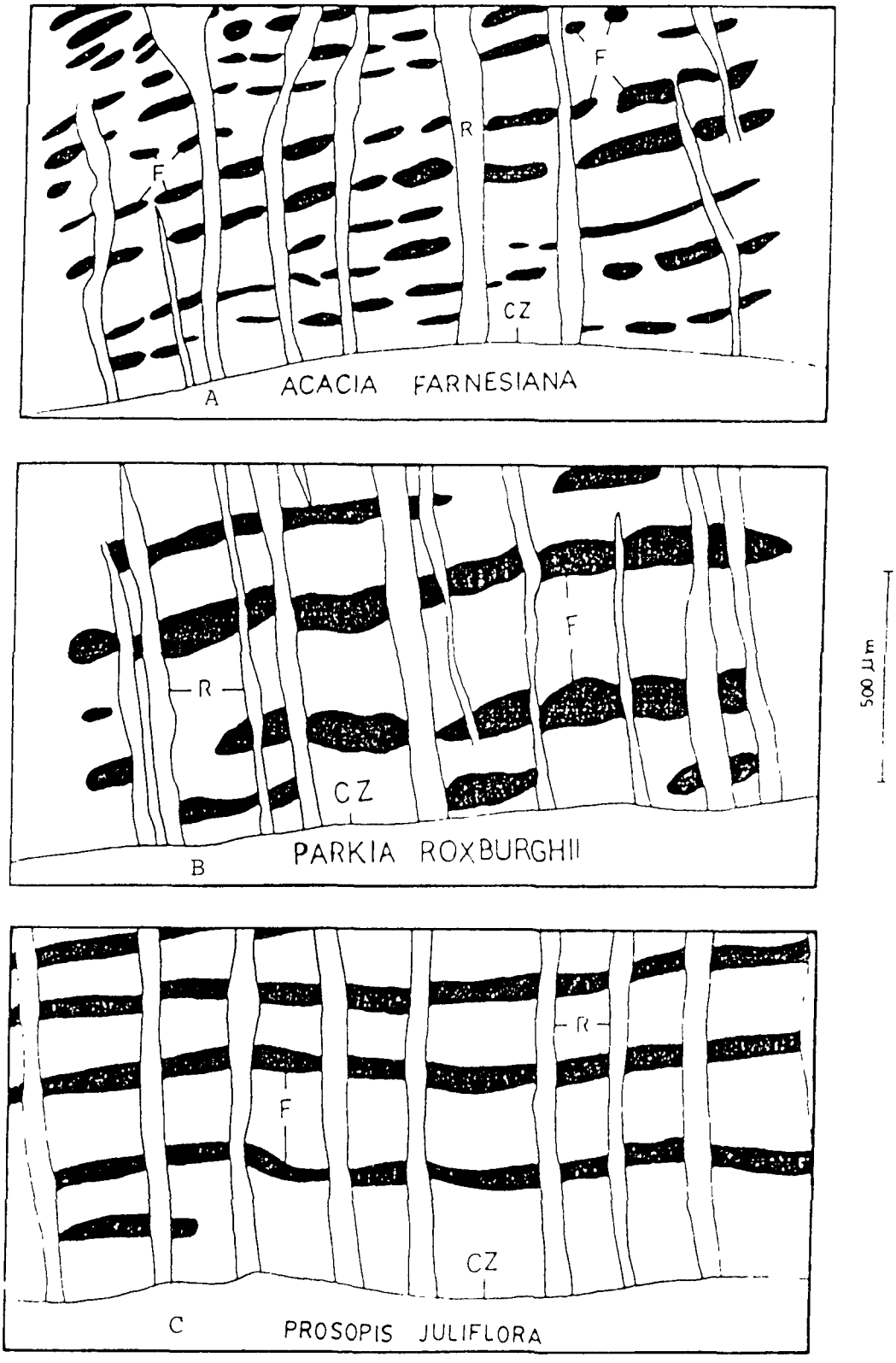


Fig. 25A-C

Camera lucida drawings of conducting phloem in t.s. showing the phloem fibre distribution (blackened areas) CZ = cambial zone, F = phloem fibres, R = phloem rays.

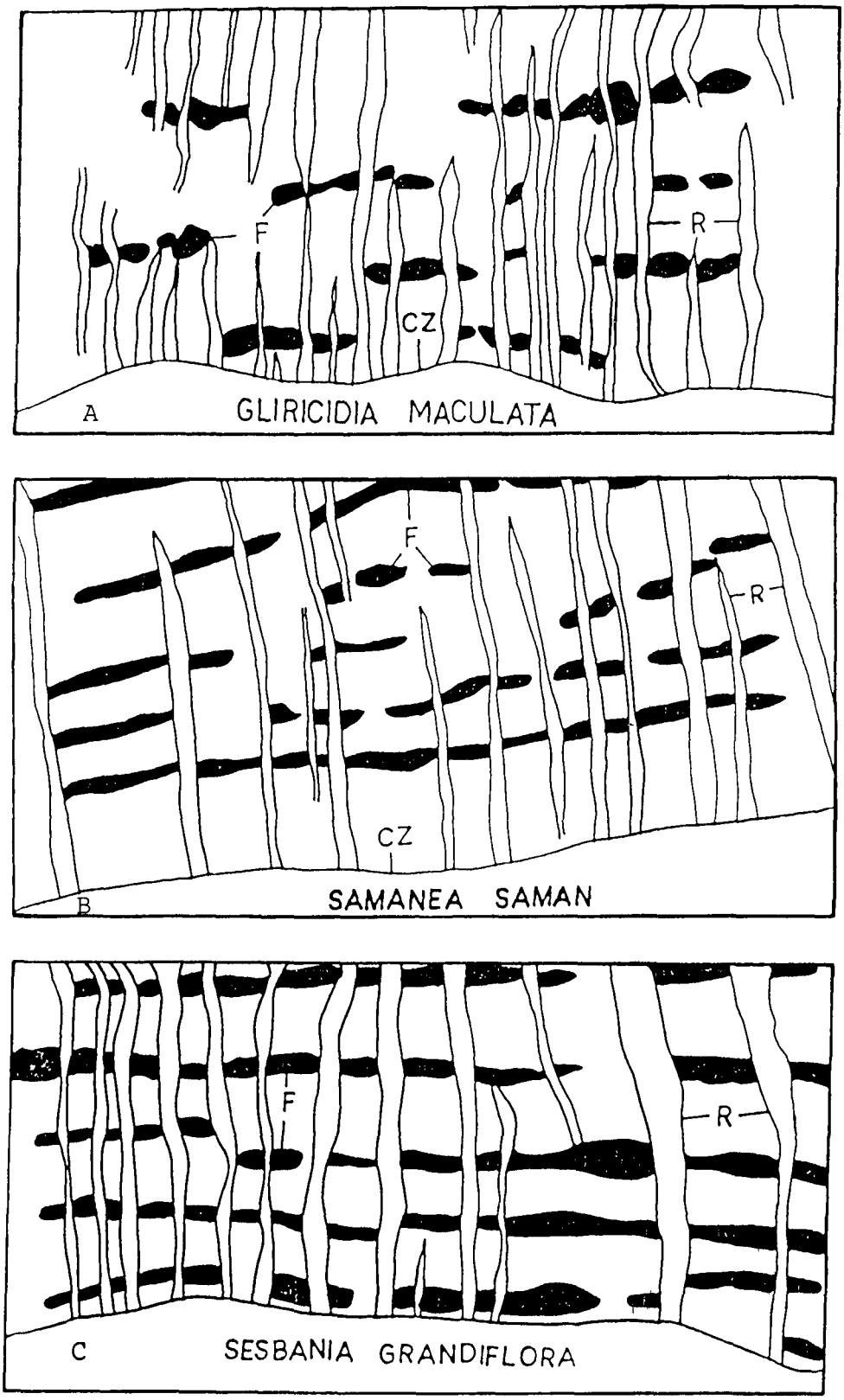


Fig.26A-C

Camera lucida drawings of conducting phloem in t.s. showing the phloem fibre distribution (blackened areas) CZ = cambial zone, F = phloem fibre, R = phloem rays.

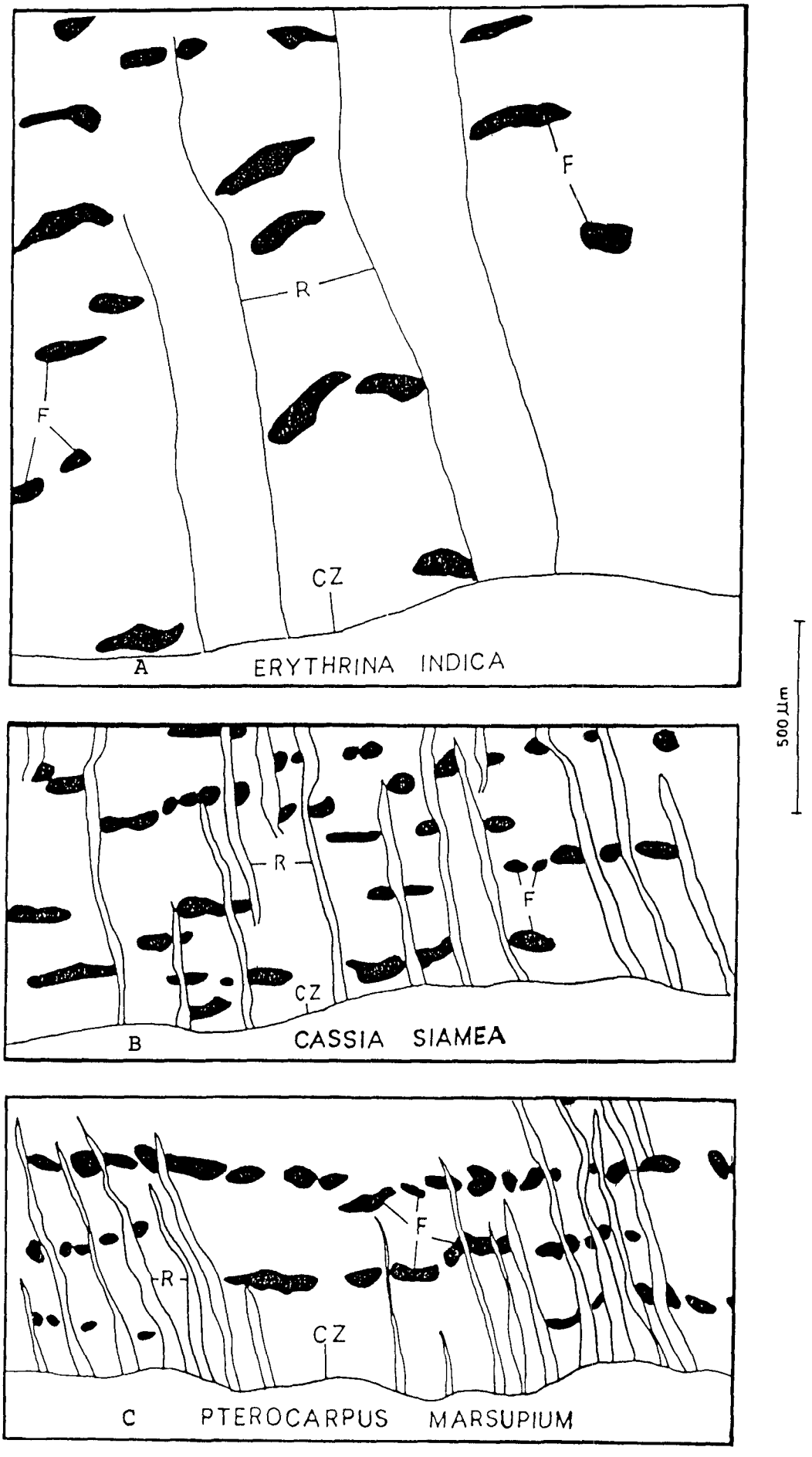


Fig.27A-C
Camera lucida drawings of conducting phloem in t.s. showing the phloem fibre distribution(blackened areas). CZ=cambial zone, F=phloem fibre, R = phloem rays.

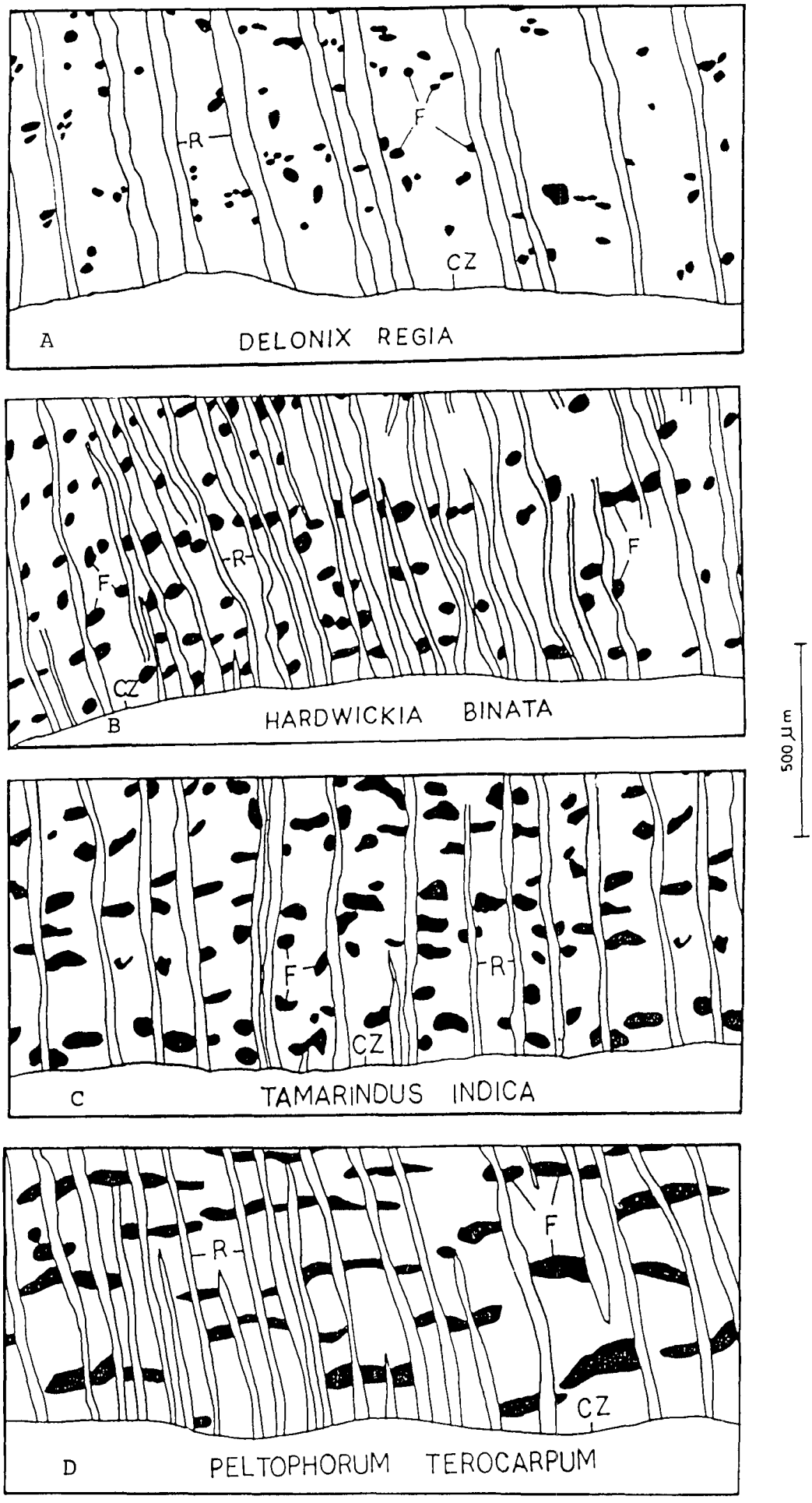


Fig.28A-D

Camera lucida drawings of conducting phloem in t.s. showing the phloem fibre distribution(blackened areas). CZ=cambia zone,F= phloem fibre, R=phloem rays.

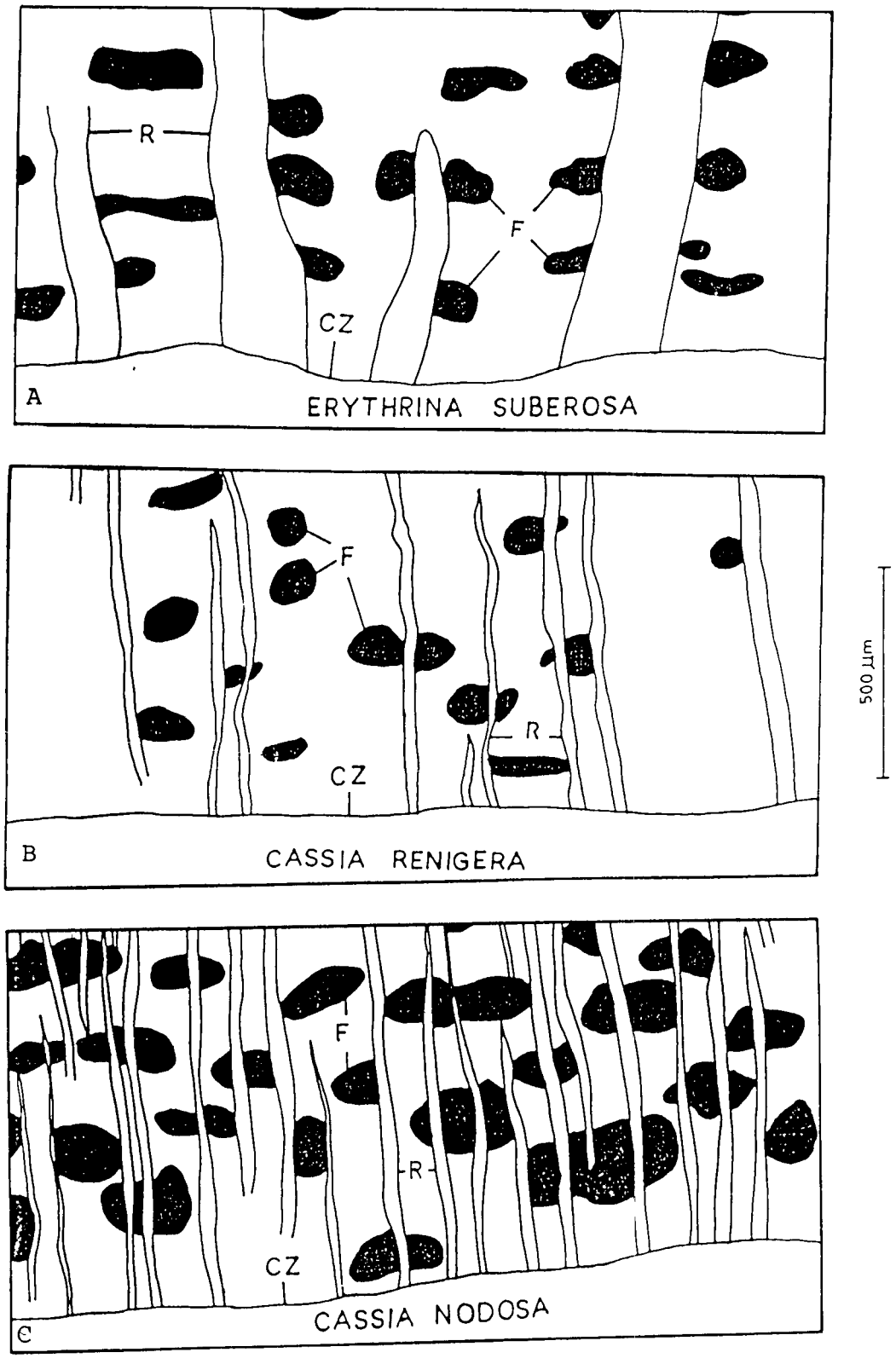


Fig. 29A-C

Camera lucida drawings of conducting phloem in t.s. showing the phloem fibre distribution (blackened areas). CZ=cambial zone, F=phloem fibre, R=phloem rays.

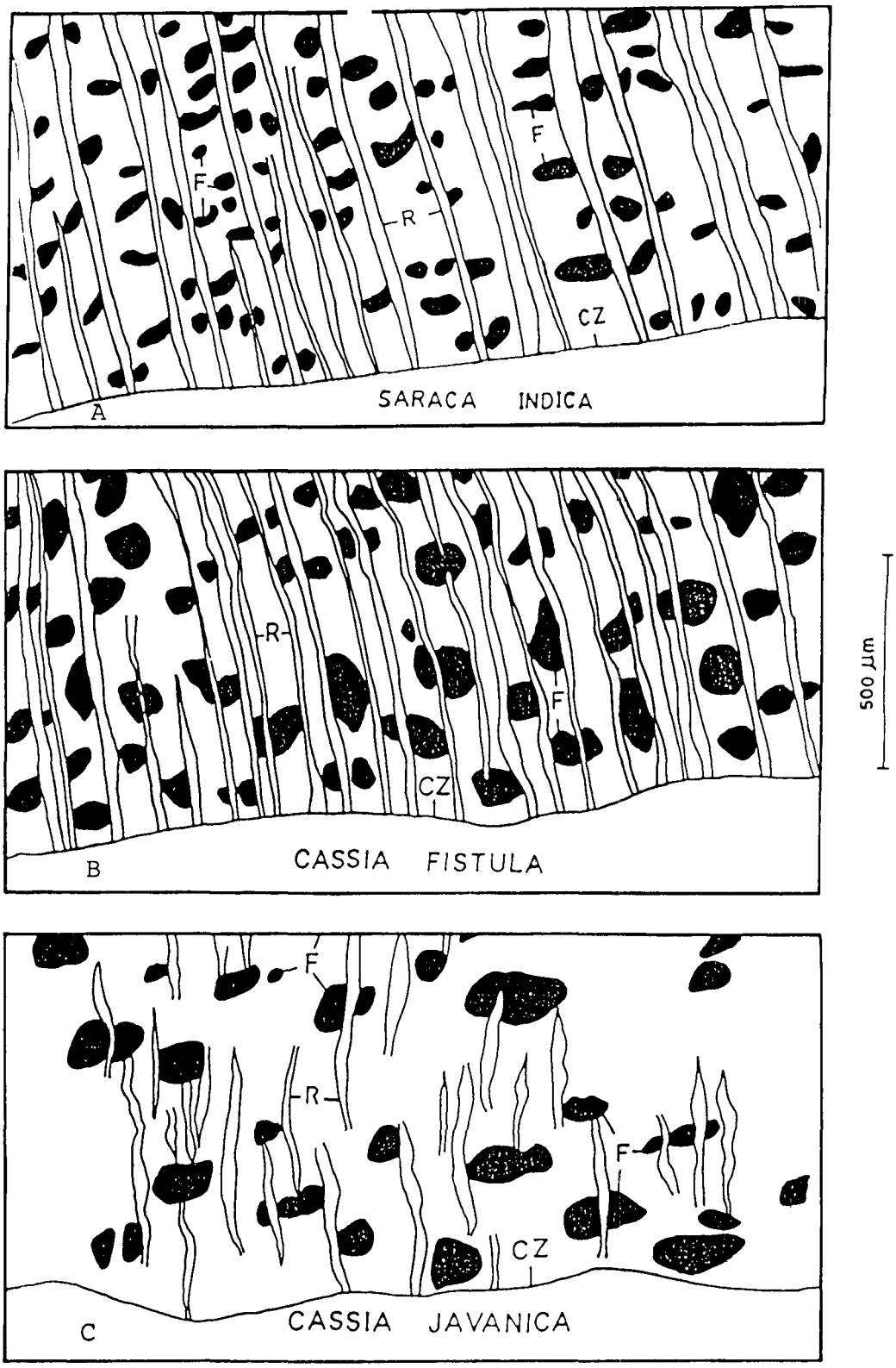


Fig. 30 A-C

Camera lucida drawings of conducting phloem in t.s. showing the phloem fibre distribution (blackened areas). CZ= cambial zone, F=phloem fibre, R=phloem rays.

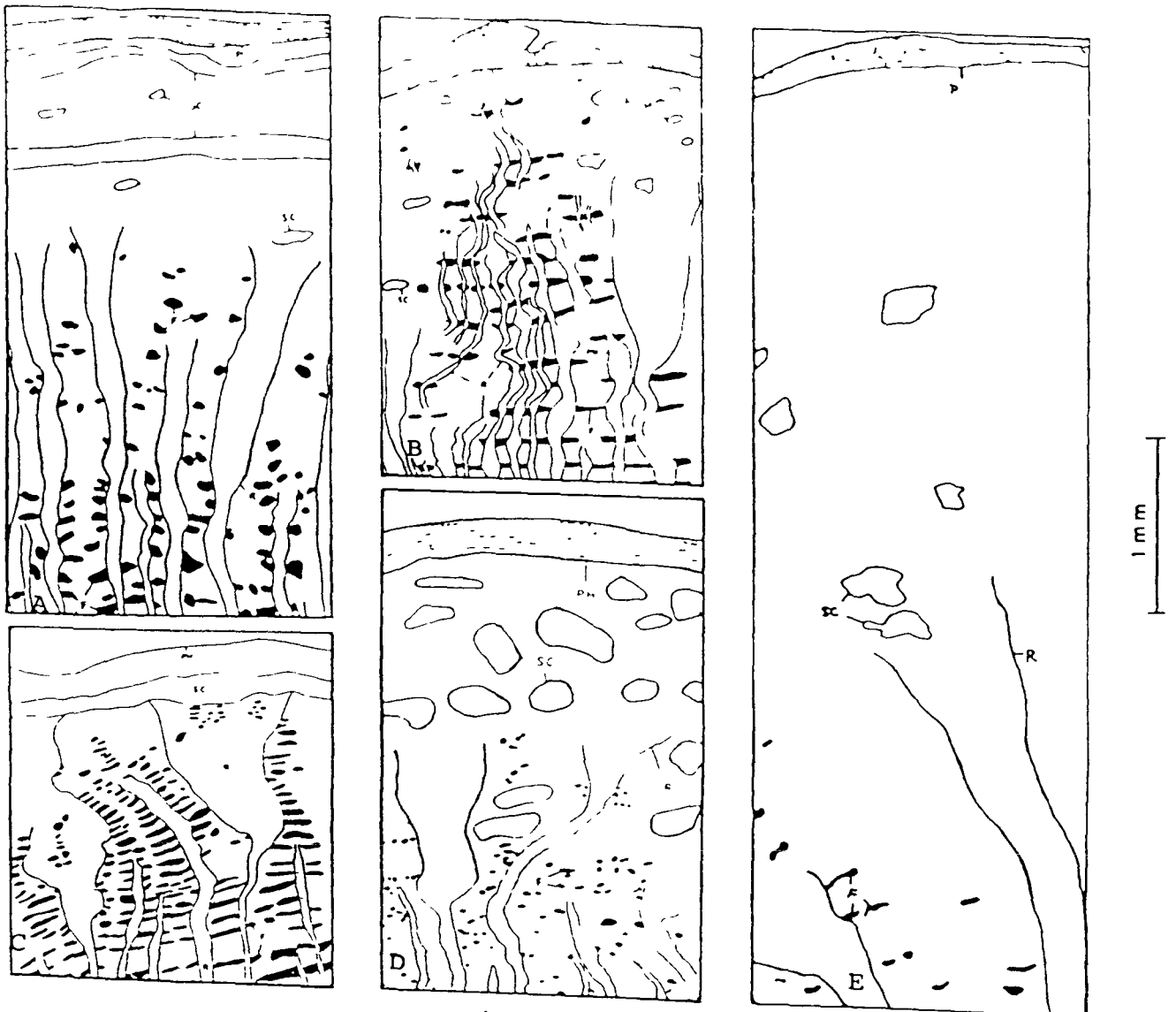


Fig.31A-D.

Distribution of sclereids in bark, t.s. (F=fibre groups, SC = sclereids groups, R=rays, P=periderm). A, Saraca indica, B, Sesbania grandiflora, C, Acacia farnesiana, D, Delonix regia, E, Erythrina indica.

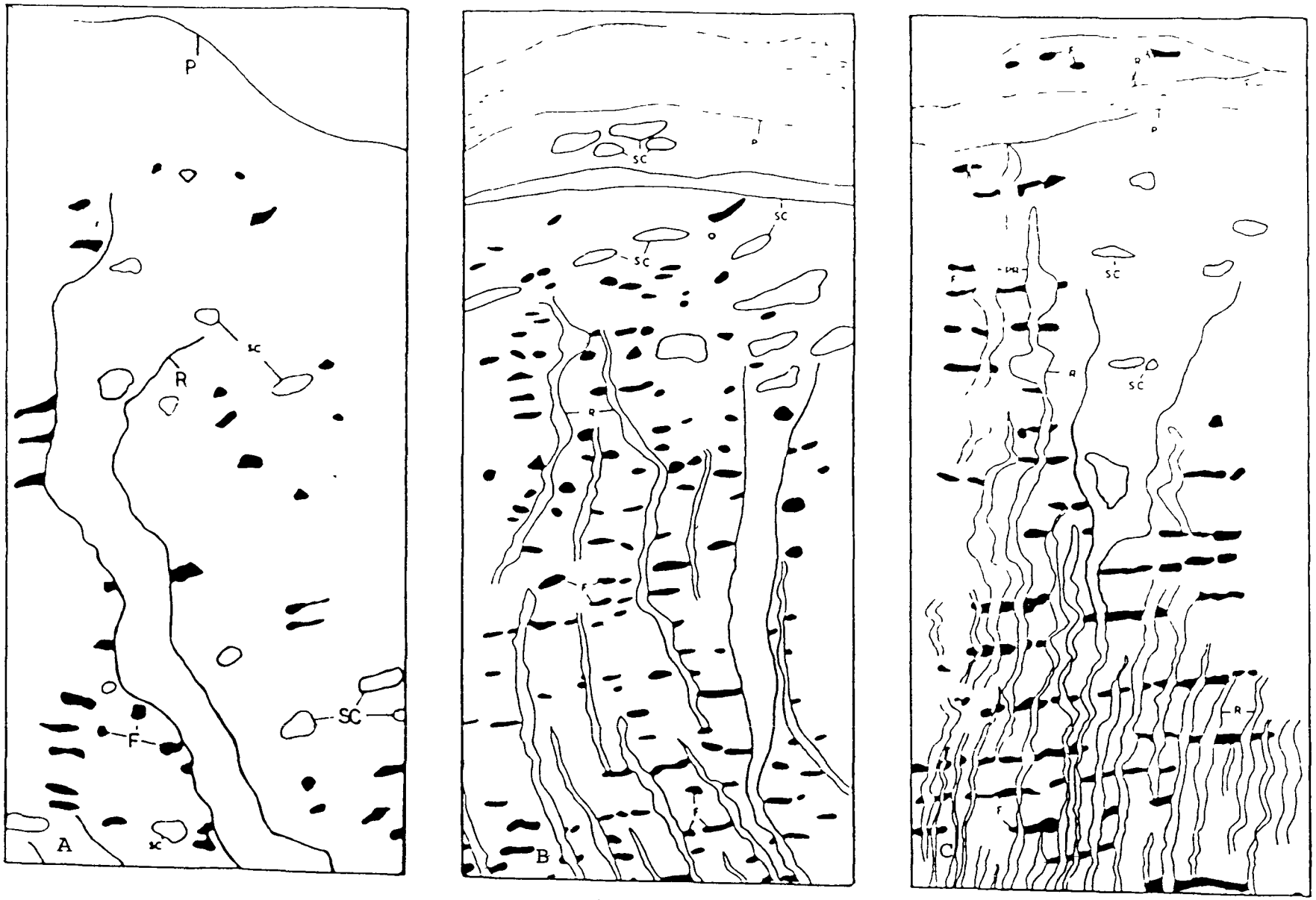


Fig.32 A-C

Distribution of sclereids in bark, t.s. (F=fibre groups, SC=sclereid groups, R=rays, P=periderm). A. Erythrina suberosa, B. Cassia siamea, C. Gliricidia maculata.

Fig.33A-B

Distribution of sclereids in bark, t.s. (F=fibre groups SC=sclereids groups,R=rays, P=periderm). A. Parkia roxburghii, B. Hardwickia binata.

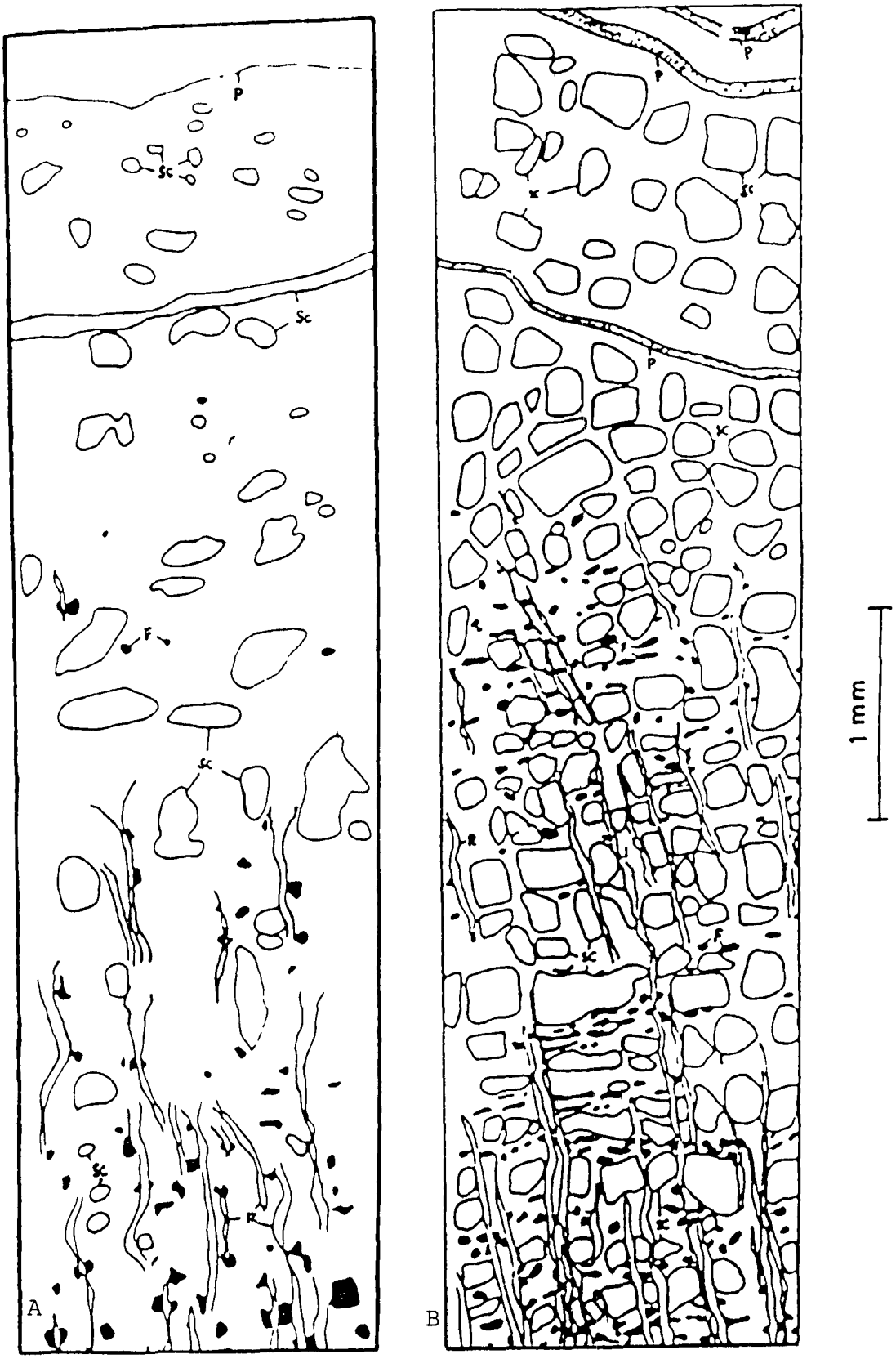


Fig.34A-B

Distribution of sclereids in bark,t.s.(F=fibre groups, SC=sclereids groups, R=rays, P=periderm). A. Cassia fistula, B. Tamarindus indica.

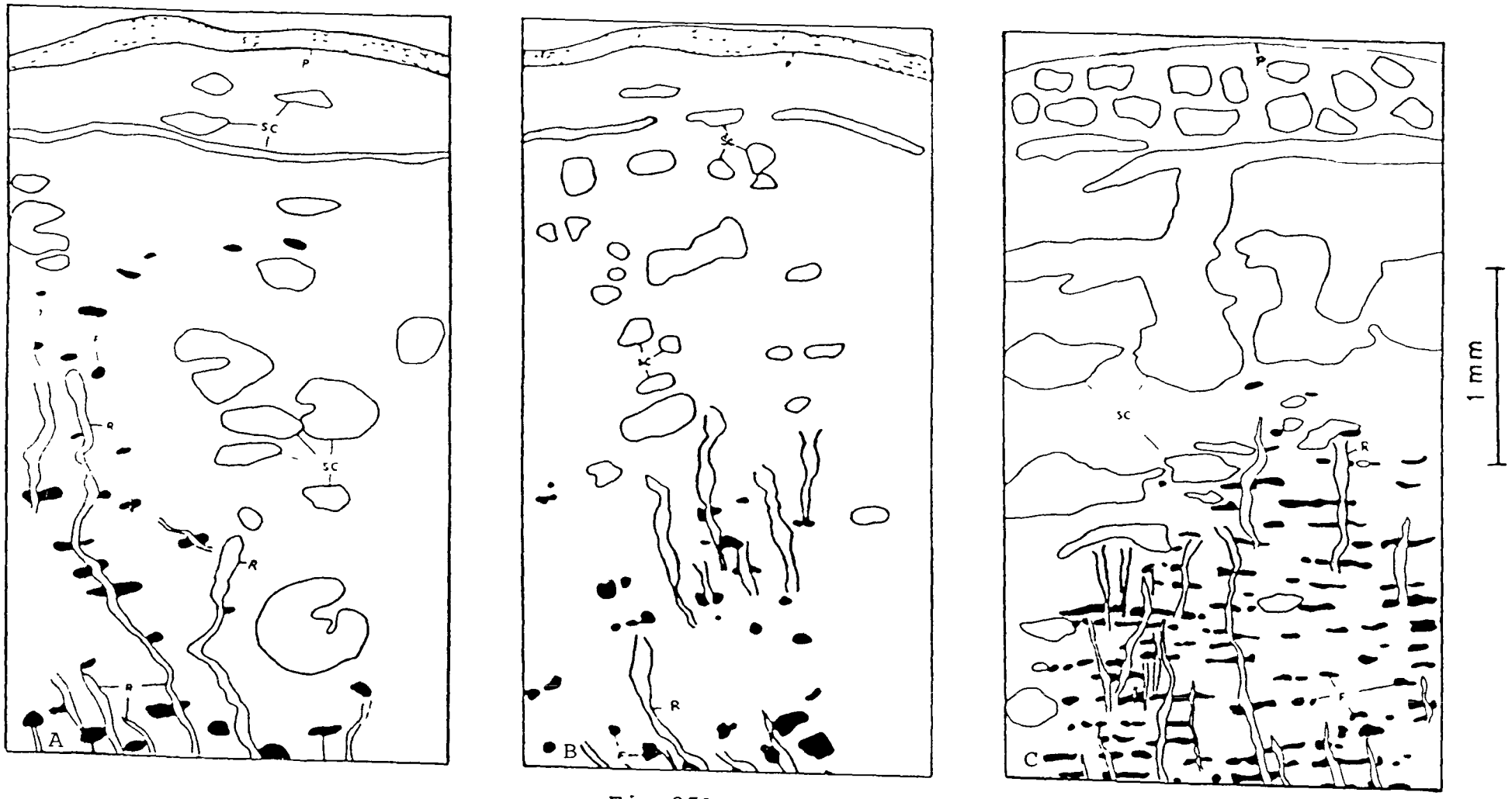


Fig.35A-C

Distribution of sclereids in bark, t.s. (F=fibre groups, SC=sclereids groups, R=rays, P= Periderm). A. Cassia renigera, B. Cassia javanica, C. Peltophorum pterocarpum.

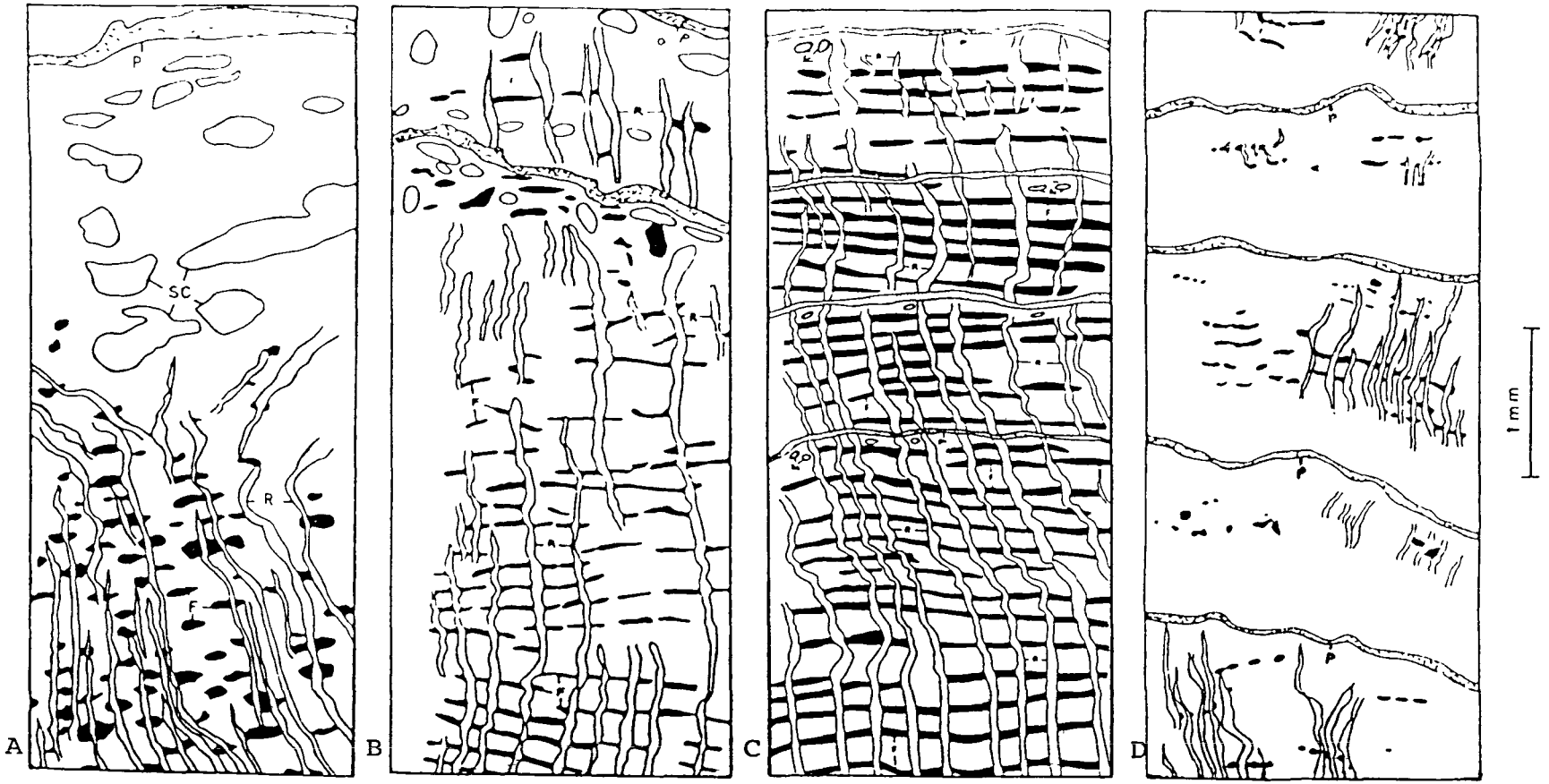


Fig.36A-D

Distribution of sclereids in bark, t.s. (F=fibre groups, SC=sclereid groups, R=rays, P=periderm). A. Cassia nodosa, B. Samanea saman, C. Prosopis juliflora, D. Pterocarpus marsupium.

SUMMARY

The present study on the bark anatomy of some cultivated leguminous trees of Aligarh (Uttar Pradesh) and Bhopal (Madhya Pradesh) has yielded the following information:

1. The barks on the basis of surface characteristics are categorized as:

   (i) Smooth or non-fissured: Acacia farnesiana, Cassia javanica, C. nodosa, Delonix regia, Erythrina indica, Gliricidia maculata, and Saraca indica.

   (ii) Shallow-fissured: Cassia siamea, Hardwickia binata, Parkia roxburghii, Sesbania grandiflora, and Tamarindus indica.

   (iii) Deep-fissured: Cassia fistula, C. renigera, Erythrina suberosa, Peltophorum pterocarpum, Prosopis juliflora, Pterocarpus marsupium and Samanea saman.

2. The bark peels off in the form of scales of various shapes and sizes in different investigated species except Erythrina indica, in which the bark sheds off in the form of thin papery flakes. The average surface area of shedded bark scales varies from 1.7 x 1 mm^2 to 125 x 43 mm^2 in different species studied viz. 1.7 x 1 mm^2 in Saraca indica 2.8 x 1.5 mm^2 in Acacia farnesiana, 3.8 x 2.7 mm^2 in Gliricidia maculata, 6.6 x 2.2 mm^2 in

Sesbania grandiflora, 7.3 x 4.4 mm^2 in Cassia nodosa, 10.8 x 10.2 mm^2 in Hardwickia binata, 11.8 x 5.7 mm^2 in Delonix regia, 12.3 x 8.4 mm^2 in Parkia roxburghii, 30.3 x 17.1 mm^2 in Cassia siamea, 43.1 x 21.5 mm^2 in C. renigera, 48.2 x 26 mm^2 in C. fistual, 50.3 x 23.3 mm^2 in Pterocarpus marsupium, 63 x 36 mm^2 in Erythrina suberosa, 64 x 32 mm^2 in Peltophorum pterocarpum, 68.5 x 30.7 mm^2 in Tamarindus indica, 92 x 11 mm^2 in Prosopis juliflora, and 125 x 43 mm^2 in Samanea saman.

3. The ray expansion tissue is prominent and visible in slash with the naked eye in Acacia farnesiana, Cassia fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Delonix regia, Erythrina indica, E. suberosa, Gliricidia maculata, Hardwickia binata, Parkia roxburghii, Peltophorum pterocarpum, Pterocarpus marsupium, Saraca indica and Sesbania grandiflora, whereas it is not visible in Prosopis juliflora, Samanea saman and Tamarindus indica.

4. Micromorphologically, the barks easily be recongised into outer and inner zones, the former consisting of rhytidome and latter of secondary phloem, the depth of which differed in different species. The secondary phloem has two distinct parts i.e., the conducting and the non-conducting ones in all the species.

5. The depth of rhytidome varies from 0.2 mm to 18.2 mm in different species viz. 0.2 mm in Erythrina indica, 0.5 mm in Cassia javanica, 0.5 mm in C. nodosa, 0.5 mm in Saraca indica, 0.7 mm in Cassia siamea, 1 mm in Acacia farnesiana, 1 mm in Delonix regia, 1.4 mm in Gliricidia maculata, 2.2 mm Sesbania grandiflora, 2.3mm in Parkia roxburghii, 2.3 mm in Peltophorum pterocarpum, 3.4 mm in Hardwickia binata, 4 mm in Prosopis juliflora, 4 mm in Tamarindus indica, 6.8 mm in Cassia fistula, 6.8 mm in Pterocarpus marsupium, 8.9 mm in Samanea saman, 16.3 mm in Erythrina suberosa,and 18.2 mm in Cassia renigera.

6. The depth of the conducting phloem ranges from 0.4 mm to 2.5 mm among the investigated species viz. 0.4 mm in Cassia siamea, 0.5 mm in Erythrina indica, 0.6 mm in Accacia farnesiana, 0.6 mm in Delonix regia, 0.7mm in Cassia fistula, 0.7 mm in C. javanica, 0.7 mm in Prosopis juliflora, 0.7 mm in Pterocarpus marsupium, 0.7 mm in Sesbania grandiflora, 0.8 mm in Hardwichia binata, 0.8 mm Saraca indica, 1 mm in Cassia renigera, 1 mm in Peltophorum pterocarpum, 1.2 mm in Erythrina suberosa, 1.5 mm in Samanea saman, 1.5 mm in Tamarindus indica, 1.7 mm in Gliricidia maculata and 2.5 mm in Cassia nodosa.

7. The depth of secondary phloem varies from 2 mm to 14 mm: 2 mm in Acacia farnesiana, 3.4 mm in Delonix regia, 4 mm in Saraca indica, 4.5 mm in Sesbania grandiflora, 5.2 mm in Prosopis juliflora, 5.3 mm in Cassia siamea, 5.6 mm in Gliricidia maculata, 5.8 mm in Cassia renigera, 6 mm in Peltophorum pterocarpum, 6.2 mm in Pterocarpus marsupium, 6.3 mm in Erythrina suberosa, 6.5 mm in Tamarindus indica, 7.2 mm in Cassia javanica, 7.7 mm in Samanea saman, 8.6 mm in Hardwickia binata, 10.3 mm in Erythrina indica, 10.6 mm in Parkia roxburghii, 11.7 mm in Cassia fistula, and 14 mm in Cassia nodosa.

8. The phloem fibres are non-septate in thirteen species except six species: Casia renigera, Hardwickia binata, Peltophorum pterocarpum, Prosopis juliflora, Sesbania grandiflora and Samanea saman have septate fibres.

9. The fibres occur in the form of continuous regular tangential bands in Acacia farnesiana, Parkia roxburghii, Prosopis juliflora, Samanea saman and Sesbania grandiflora, as fascicles of varying size arranged more or less in discontinuous tangential bands in Cassia nodosa, C. siamea, Erythrina suberosa, Gliricidia maculata, Hardwickia binata, Peltophorum pterocarpum, and Pterocarpus marsupium and as irregularly distributed isolated elements or groups of different size in Cassia fistula, C. javanica,

C. nodosa, C. renigera, Delonix regia, Erythrina indica, Saraca indica and Tamarindus indica.

10. The total average amount of fibres in the secondary phloem constitute about 5.96% in Erythrina indica, 7.06% in Delonix regia, 8.45% in Erythrina suberosa, 10.04% in Parkia roxburghii, 10.09% in Gliricidia maculata, 10.34% in Hardwickia binata, 10.94% in Pterocarpus marsupium, 11.69% in Cassia javanica, 12.30% in Prosopis juliflora, 12.56% in Cassia renigera, 13.26% in Tamarindus indica, 13.35% in Cassia siamea, 13.59% in C. fistula 13.65% in Samanea saman, 14.23% in Peltophorum pterocarpum, 16.27% in Saraca indica, 17.48% in Sesbania grandiflora, 18.39% in Acacia farnesiana and 22.47% in Cassia nodosa.

11. The mean length of fibres varies from 592.80 µm to 1742.08 µm in various investigated species viz. 592.80 µm in Cassia renigera, 637.76 µm in C. nodosa, 650.88 µm in C. javanica, 770.56 µm in Gliricidia maculata, 839.52 µm in Cassia fistula, 851.20 µm in Peltophorum pterocarpum, 900.96 µm in Tamarindus indica 976.64 µm in Prosopis juliflora, 995.36 µm in Cassia siamea, 1055.68 µm in Samanea saman, 1083.36 µm in Saraca indica, 1111.20 µm Parkia roxburghii, 1198.56 µm in Acacia farnesiana, 1201.76 µm in Sesbania grandiflora, 1236.81 µm in Pterocarpus marsupium 1281.28 µm in Erythrina suberosa,1548.64µm

in Hardwickia binata 1599.36 µm in Erythrina indica and 1742.08 µm in Delonix regia whereas the width varies from 12.22 µm to 31.20 µm viz. 12.22 µm in Hardwickia binata, 14.56 µm in Parkia roxburghii, 16.16 µm in Tamarindus indica 16.32 µm in Peltophorum pterocarpum, 17.92 µm in Samanea saman, 18.08 µm in Delonix regia, 18.24 µm in Erythrina indica, 19.60 µm in Cassia siamea, 19.84 µm in C. renigera, 19.68 µm in C. fistula, 20 µm in C. javanica, 20 µm in Sesbania grandiflora, 20.63 µm in Prosopis juliflora, 20.77 µm in Acacia farnesiana 22.08 µm in Gliricidia maculata, 23.20 µm in Cassia nodosa, 28.22 µm in Pterocarpus marsupium and 31.20 µm in Erythrina suberosa.

12. All species have sieve tubes but the arrangement varies. The arrangement is stratified in Erythrina indica, E. suberosa, Gliricidia maculata, Pterocarpus marsupium and Sesbania grandiflora and non-stratified in Acacia farnesiana, Cassia fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Delonix regia, Hard wickia binata, Parkia roxburghii, Peltophorum pterocarpum, Prosopis juliflora, Samanea saman, Saraca indica and Tamarindus indica.

13. The arrangement of the rays is stratified in Gliricidia maculata, Peltophorum pterocarpum, Pterocarpus marsupium and Sesbania grandiflora and non-stratified in Acacia

farnesiana, C. fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Erythrina indica, E, suberosa, Delonix regia, Hardwickia binata, Parkia roxburghii, Prosopis juliflora, Samanea saman Saraca indica and Tamarindus indica.

14. The sieve-tube elements possess simple sieve plates on their end walls which are either almost transeverse or slightly inclined in Erythrina indica, E. suberosa, Gliricidia maculata, Pterocarpus marsupium and Sesbania grandiflora, whereas in Acacia farnesiana, Cassia fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Delonix regia, Hardwickia binata, Parkia roxburghii, Peltophorum pterocarpum, Prosopis juliflora, Samanea saman, Saraca indica and Tamarindus indica, have inclined end walls with compound sieve plates.

15. The mean proportion of sieve-tube elements in the conducting phloem ranges from 6.01% to 54.63% in the different species studied viz. 6.01% in Hardwickia binata, 7.19% in Cassia siamea, 8.35% in Peltophorum pterocarpum, 10.62% in Parkia roxburghii, 11.78% in Cassia javanica, 13.62% in Pterocarpus marsupium, 14.82% in Cassia fistula, 15.13% in C. nodosa, 15.80% in Sesbania grandiflora, 15.98% in Gliricidia maculata, 16.99% in Tamarindus indica, 17.40% in Cassia renigera, 20.37% in Erythrina suberosa, 20.78%

in Prosopis juliflora, 27.49% in Erythrina indica, 28.87%in Samanea saman, 29.04% in Acacia farnesiana, 40.79% in Saraca indica and 54.63% in Delonix regia.

16. The mean length of sieve-tube elements is greater in the species with non-stratified arrangement than those with stratified pattern, confirming the established evolutionary trend. The mean sieve-tube cell length measures 184.48 µm in Samanea saman, 189.76 µm in Gliricidia maculata, 190.40 µm in Pterocarpus marsupium, 194.56 µm in Sesbania grandiflora, 224.64 µm in Prosopis juliflora, 240 µm in Tamarindus indica 245.28 µm in Erythrina indica, 252.16 µm in Hardwickia binata, 259.20 µm in Cassia nodosa, 269.60 µm in C. renigera, 290.24 µmin Acacia farnesiana, 322.03 µm in Cassia fistula, 327.52 µm in Parkia roxburghii, 351.36 µm in Peltophorum pterocarpum, 353.16 µm in Erythrina suberosa, 353.22 µm, in Cassia siamea, 364 µm in C. javanica, 380.96 µm in Saraca indica and 445.28 µm in Delonix regia, whereas the width measures 17.92 µm in Pterocarpus marsupium 19.23 µm in Prosopis juliflora, 21.60 µm in Gliricidia maculata, 24.64 µm in Cassia fistula, 26.88 µm in Tamarindus indica, 27.78 µm in Peltophorum pterocarpum, 28.32 µm in Hardwickia binata, 28.80 µm in Cassia nodosa, 31.58 µm in C. siamea, 32 µm in Acacia farnesiana, 32.16 µm in Sesbania grandiflora,

32.80 µm in Cassia javanica, 34.05 µm in Parkia roxburghii, 34.56 µm in Erythrina indica, 35.55 µm in Saraca indica, 36.19 µm in Erythrina suberosa 38.30 µm in Delonix regia, 38.40 µm in Samanea saman and 40.16 µm in Cassia renigera.

17. The phloem rays are homogeneous having only procumbent cells in all the investigated species except Hardwickia binata in which they are homogeneous as well as heterogeneous.

18. The arrangement of rays is non-stratified in all the investigated species except Gliricidia maculata, Peltophorum pterocarpum, Pterocarpus marsupium and Sesbania grandiflora.

19. The rays are usually narrow in Cassia fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Delonix regia, Gliricidia maculata, Hardwickia binata, Parkia roxburghii, Peltophorum pterocarpum, Prosopis juliflora, Pterocarpus marsupium, Samanea saman, Saraca indica, Sesbania grandiflora and Tamarindus indica and broad in Acacia farnesiana Erythrina indica and E. suberosa.

20. The rays are cent percent narrowed i.e. 1-3 seriate in Cassia fistula, C. javanica, C. nodosa, C. renigera, C.

siamea, Hardwickia binata, Peltophorum pterocarpum, Pterocarpus marsupium, Saraca indica, Sesbanaia grandiflora and Tamarindus indica, 97% in Gliricidia maculata, 95% in Samanea saman, 77% in Prosopis juliflora and 59% in Delonix regia. In Acacia farnesiana, Erythrina suberosa, E. indica the rays are generally broad having 77%, 87% and 88% respectively.

21. The mean height of rays varies from 93.76 µm (5.74 cells) to 2384.80 µm (64.75 cells) in different species viz. 93.76 µm (5.87 cells) in Samanea saman, 126.40 µm (5.74 cells) in Sesbania grandiflora, 129.76 µm (8.06 cells) in Cassia renigera 130.56 µm (6.64 cells) in Pterocarpus marsupium, 147.20 µm (6.32 cells) in Gliricidia maculata, 148 µm (8.36 cells) in Cassia javanica, 172.80 µm (9.66 cell) in C. nodosa, 182.88 µm (10.76 cells) in Peltophorum pterocarpum, 186.11 µm(11.20 cells)in Tamarindus indica, 198.72 µm (9.66 cells) in Cassia siamea, 211.04 µm (10.59 cells) in C. fistula,230.08 µm (16.65 cells)in Prosopis juliflora, 246.72 µm (8.63 cells) in Hardwickia binata, 288.96 µm (16.29 cells) in Parkia roxburghii, 318.88 µm (12.50 cells) in Saraca indica 329.60 µm (23.12 cells) in Acacia farnesiana, 343.20 µm (17.18 cells) in Delonix regia, 1350.40 µm (47.40 cells) in Erythrina suberosa and 2384.80 µm (64.75 cells) in E. indica, whereas the width varies from

18.90 µm (1.18 cells) to 470.80 µm (12.10 cells) viz. 18.90 µm (1.18 cells) in Peltophorum pterocarpum, 20.64 µm (1.24 cells) in Cassia fistula, 27.36 µm (1.73 cells) in Hardwickia binata, 29.92 µm (2.18 cells) in Tamarindus indica, 32.32 µm (2.22 cells) in Samanea saman, 34.56 µm (3.22 cells) in Prosopis juliflora, 36.32 µm (2.71 cells) in Cassia renigera, 36.48 µm (2.30 cells) in C. siamea, 37.44 µm (2.48 cells) in Pterocarpus marsupium, 38.40 µm (2.04 cells) in Gliricidia maculata, 38.88 µm (2.36 cells) in Cassia nodosa, 39.36 µm (1.70 cells) in Saraca indica, 41.60 µm (2 cells) in Sesbania grandiflora 51.04 µm (2.75 cells) in Parkia roxburghii, 51.84 µm (2.92 cells) in Delonix regia, 54.08 µm (4.04 cells) in Acacia farnesiana 297.60 µm (10.20 cells) in Erythrina suberosa and 470.80 µm (12.10 cells) in E. indica.

22. The rays are mostly short (1.10 cells) in Cassia fistula, C. javanica, C. nodosa, C. renigera, C. siamea, Gliricidia maculata, Hardwickia binata, Pterocarpus marsupium, Samanea saman, Sesbania grandiflora, medium (11.20 cells) in Delonix regia, Parkia roxburghii, Peltophorum pterocarpum, Prosopis juliflora, Saraca indica and Tamarindus indica and tall (above 20 cells) only in Acacia farnesiana, Erythrina indica and E. suberosa.

23. Ray frequency varies from 1.56 to 71.57 rays/mm^2 in the conducting phloem zone of different species viz. Erythrina indica (1.56), E. suberosa (2.41), Acacia farnesiana (12.12), Delonix regia (15.60), Parkia roxburghii (29.55), Prosopis juliflora (30.92), Saraca indica (32.95), Sesbania grandiflora (37.48), Cassia nodosa (40.92), C. javanica (42.32), C. renigera (45.29), Hardwickia binata (50.12), Cassia siamea (53.26), Peltophorum pterocarpum (55.77), Cassia fistula (58.11), Tamarindus indica (61.29), Samanea saman (63.09), Pterocarpus marsupium (65.83) & Gliricidia maculata (71.57).

24. The area occupied by the rays is as high as 33.33% and as low as 10.08% in the conducting phloem in the species studies viz. 10.08% in Pterocarpus marsupium, 13.36% in Peltophorum pterocarpum, 13.61% in Cassia renigera, 14.48% in Prosopis juliflora, 14.96% in Cassia siamea, 15.05% in C. javanica, 15.15% in C. nodosa, 15.75% in Acacia farnesiana 17.19% in Hardwickia binata, 18.59% in Delonix regia, 19.02% in Cassia fistula, 19.63% in Samanea saman, 20.35% in Gliricidia maculata, 21.30% in Sesbania grandiflora, 22.82% in Saraca indica 24.92% in Parkia roxburghii, 25.15% in Tamarindus indica, 27.80% in Erythrina indica and 33.33% in Erythrina suberosa.

25. The area occupied by axial parenchyma in the conducting phloem has a wide variation from 18.72% to 65.74% : 18.72% in Delonix regia, 20.12% in Saraca indica, 36.82% in Acacia farnesiana, 37.85% in Samanea saman, 38.75% in Erythrina indica, 44.60% in Tamarindus indica, 45.33% in Sesbania grandiflora, 46.44% in Prosopis juliflora, 40.25% in Cassia nodosa, 52.57% in C. fistula, 53.58% in Gliricidia maculata, 54.42% in Parkia roxburghii, 56.43% in Cassia renigera, 61.05% in Peltophorum pterocarpum, 61.48% in Cassia javanica, 64.50% in C. siamea, 65.36% in Pterocarpus marsupium and 65.74 % in Hardwickia binata.

26. Brachy-type sclereids are found in the non-conducting phloem and phelloderm except Pterocarpus marsupium. The mean length of sclereids varies from 50.18 µm to 183.65 µm in investgated species viz. 50.18 µm in Prosopis juliflora, 57.52 µm in Gliricidia maculata, 54.15 µm in Samanea saman 54.78 µm in Acacia farnesiana, 61.88 µm in Hardwickia binata 63.20 µm in Parkia roxburghii, 69.60 µm in Sesbania grandiflora 67.76 µm in Tamarindus indica, 73.60 µm in Cassia renigera, 87.95 µm in Saraca indica, 90.75 µm in Delonix regia, 98.08 µm in Erythrina indica, 104.16 µm in Cassia fistula, 113.76 µm in C. nodosa, 123.20 µm in C. javanica, 124.64 µm in C. siamea

170.24 µm in Peltophorum pterocarpum, & 183.65 µm in Erythrina suberosa, whereas the width varies from 30.82 µm to 61.38 µm in various species studied viz. 30.82 µm in Cassia siamea, 33.47 µm in Prosopis juliflora, 34.40 µm in Cassia renigera, 34.52 µm in Acacia farnesiana, 35.84 µm in Cassia javanica, 36.64 µm in Delonix regia, 37.76µm in Parkia roxburghii, 38.08 µm in Tamarindus indica, 41.98 µm in Cassia nodosa, 42.08 µm in Erythrina indica, 42.24 µm in Peltophorum pterocarpum, 42.90 µm in Saraca indica, 48.50 µm in Cassia fistula, 48.80 µm in Sesbania grandiflora and 61.38 µm in Erythrina suberosa.

27. The amount of sclereids in the non-conducting and phelloderm parts varies from 1.50% to 41.62% in different species viz. 1.50% in Hardwickia binata, 2.05% in Prosopis juliflora, 2.32% in Erythrina indica, 2.65% in Sesbania grandiflora, 3.04% in Erythrina suberosa, 4.12% in Parkia roxburghii, 9.11% in Acacia farnesiana, 9.74% in Cassia javanica, 10.55% in Samanea saman, 11.95% Cassia fistula, 13.18% in C. siamea, 13.57% in C. renigera, 16.48% in C. nodosa, 19.20% in Saraca indica, 26.38% in Peltophorum pterocarpum, 27.50% in Delonix regia and 41.62% in Tamarindus indica.

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*Original not seen.

Plate - I. A. Tree trunk of *Acacia farnesiana* showing fissuring of the bark.

B. Tangential longitudinal section of conducting phloem of *A. farnesiana* showing sieve plate (black arrow) and lateral sieve areas (white arrow) (400X).

C. Transverse section of conducting phloem zone of *A. farnesiana* showing sieve-tube elements (black arrow) and parenchyma (white arrow) (250X).

D. Tree trunk of *Cassia fistula* showing fissuring of the bark.

E. Tangential longitudinal section of conducting phloem of *C. fistula* showing sieve plate (black arrow) and lateral sieve areas (white arrow) (400X).

F. Transverse section of conducting phloem of *C. fistula* showing sieve-tube elements (black arrow) and parenchyma (white arrow) (250X).

PLATE I

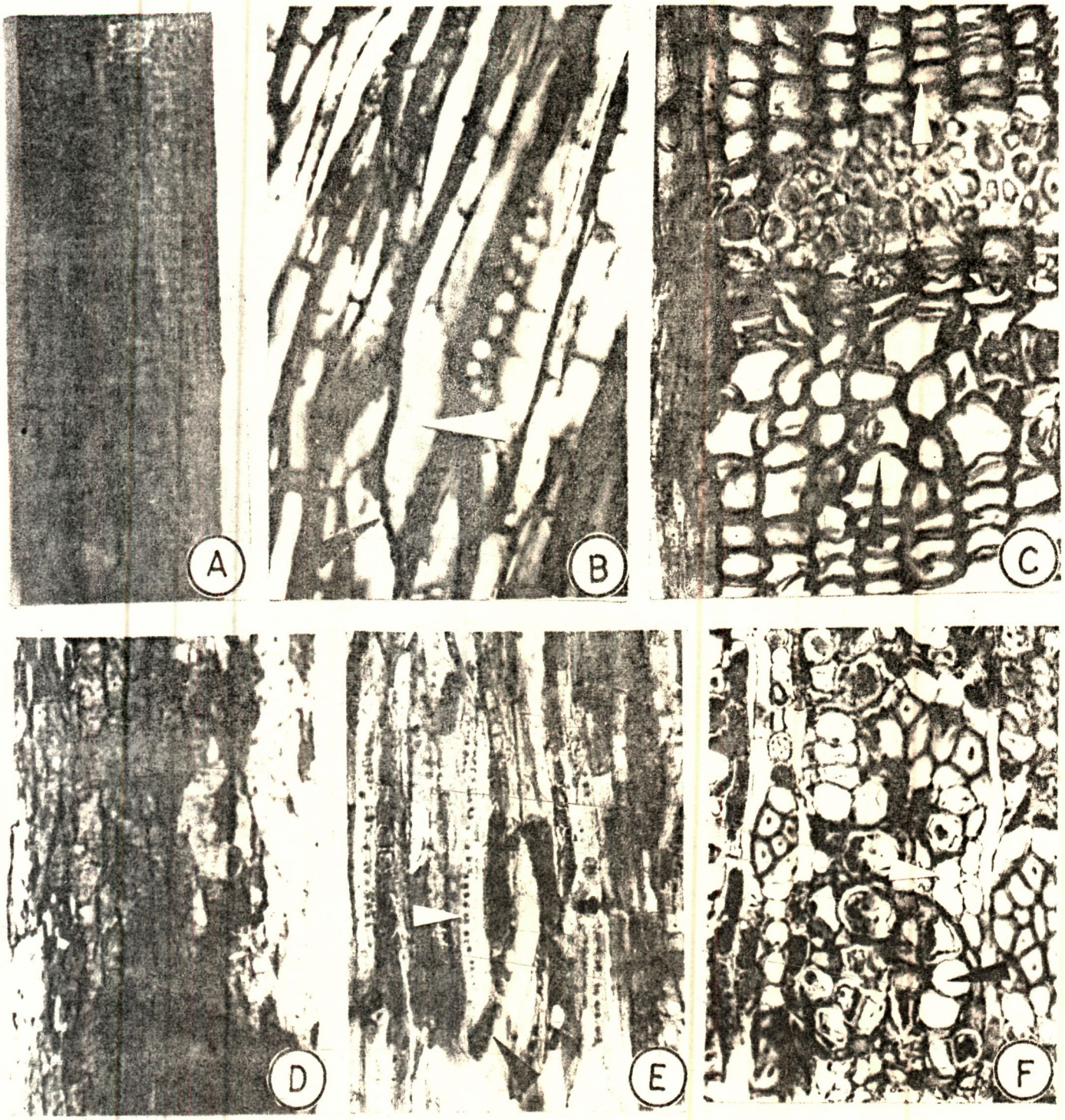

Plate - II. A. Tree trunk of Cassia javanica showing fissuring of the bark.

B. Tangential longitudinal section of conducting phloem of C. javanica showing sieve plate (black arrow) and lateral sieve areas (white arrow) (400X).

C. Transverse section of conducting phloem of C. javanica showing sieve-tube elements (black arrow) and parenchyma (white arrow) (400X).

D. Tree trunk of Cassia nodosa showing fissuring of the bark.

E. Tangential longitudinal section of conducting phloem of C. nodosa showing sieve plate (black arrow) (400X).

F. Transverse section of conducting phloem part of C. nodosa showing sieve-tube elements (black arrow) and parenchyma (white arrow) (250X).

PLATE II

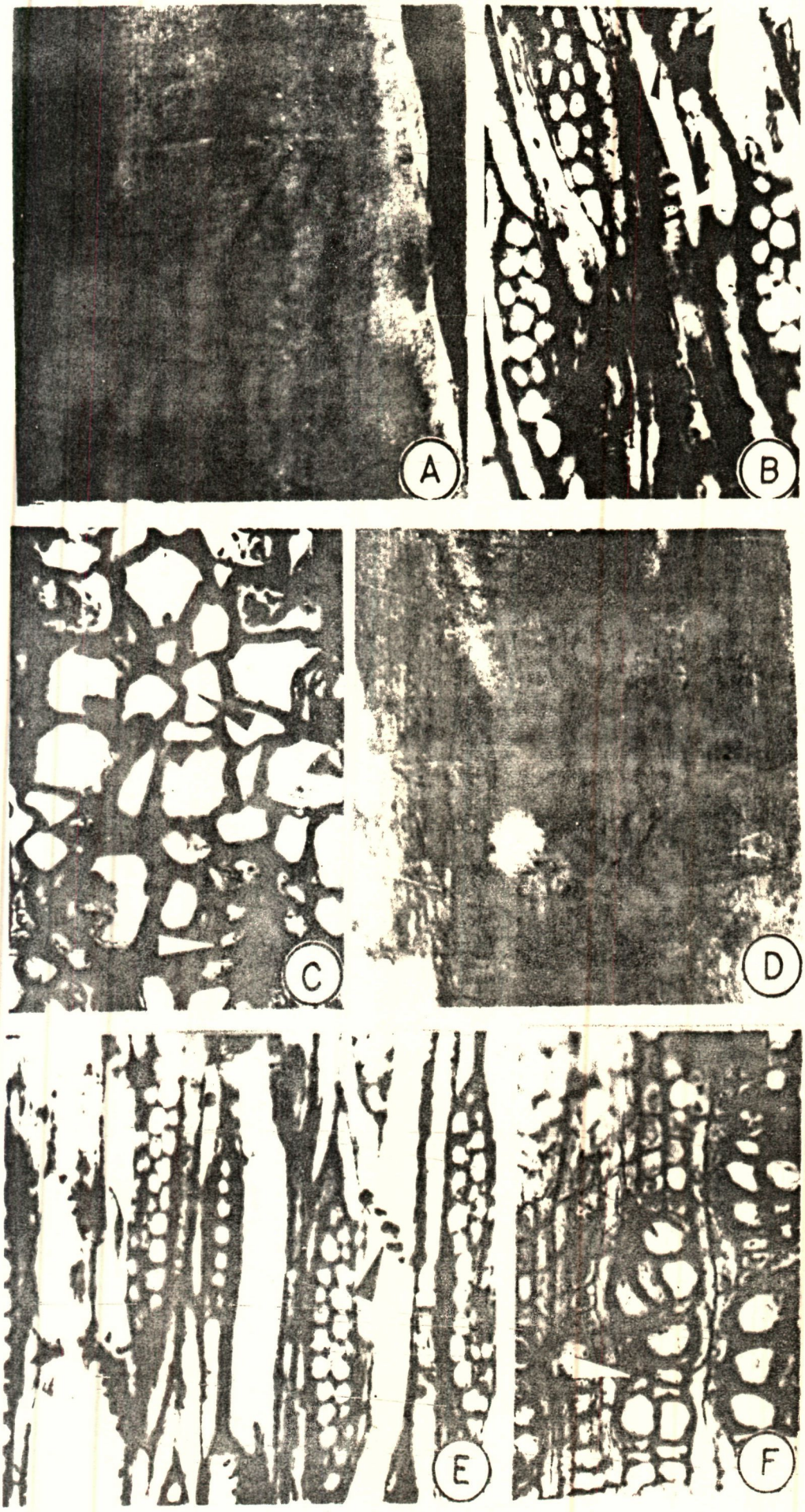

Plate - III. A. Tree trunk of *Cassia renigera* showing fissuring of the bark.

B. Tangential longitudinal section of conducting phloem of *C. renigera* showing sieve plate (black arrow) and lateral areas (white arrow) (250X).

C. Transverse section of conducting phloem of *C. renigera* showing sieve-tube elements (black arrow) and parenchyma (white arrow) (250X).

D. Tree trunk of *Cassia siamea* showing fissuring of the bark.

E. Tangential longitudinal section of conducting phloem zone of *C. siamea* showing sieve plate(black arrow) and lateral sieve areas (white arrow) (250X).

F. Transverse section of conducting phloem zone of *C. siamea* showing sieve-tube elements (black arrow) and parenchyma (white arrow) (250X).

PLATE III

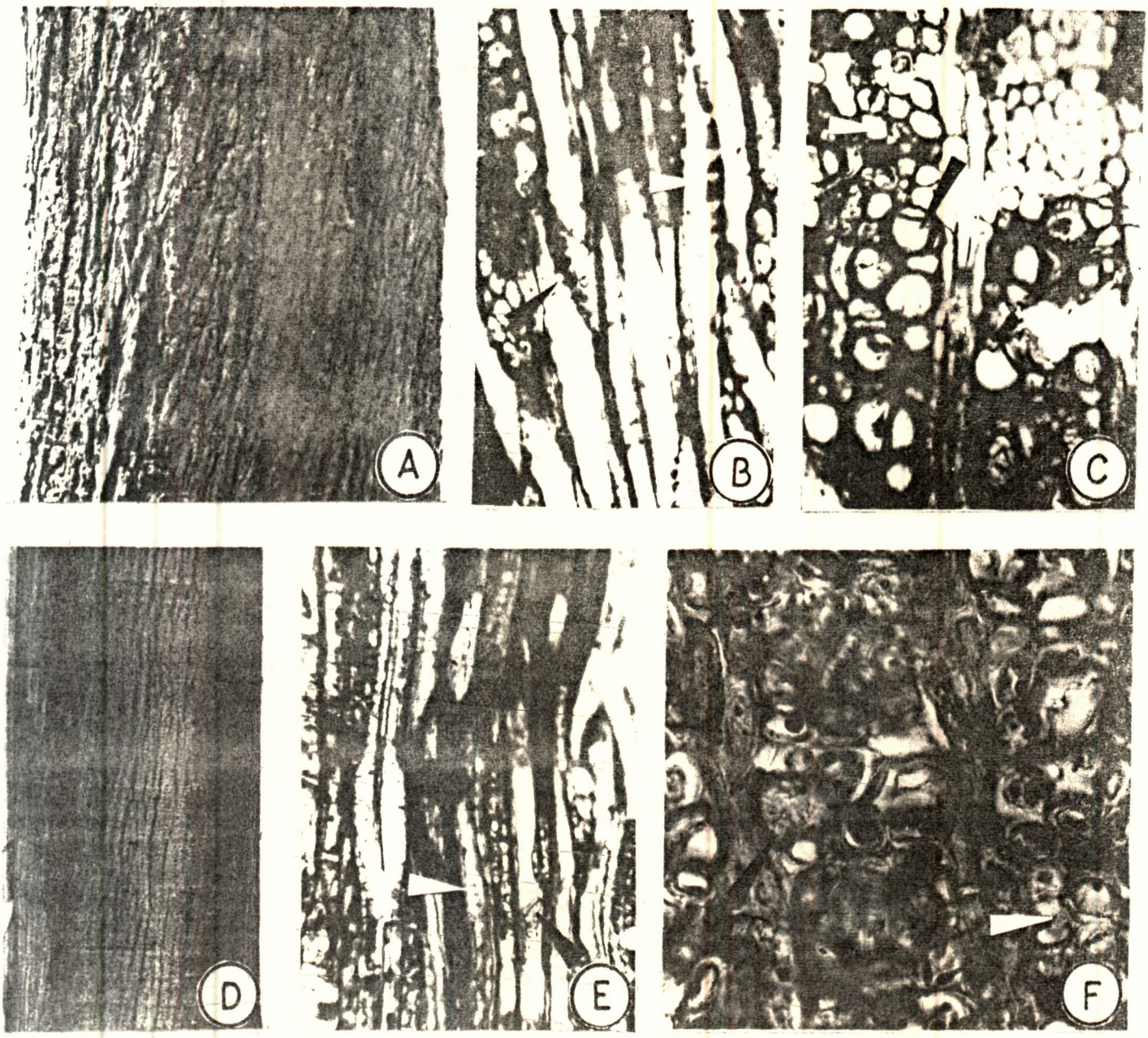

Plate - IV.

A. Tree trunk of Erythrina indica showing fissuring of the bark.

B. Tangential longitudinal section of conducting phloem of E. indica showing stratified arrangement of sieve-tube elements (100X).

C. Transverse section of conducting phloem zone of E. indica showing sieve-tube elements (black arrow) and parenchyma (white arrow) (100X).

D. Tangential longitudinal section of conducting phloem of E. indica showing sieve plate (black arrow) and lateral sieve areas (white arrow) (400X).

PLATE IV

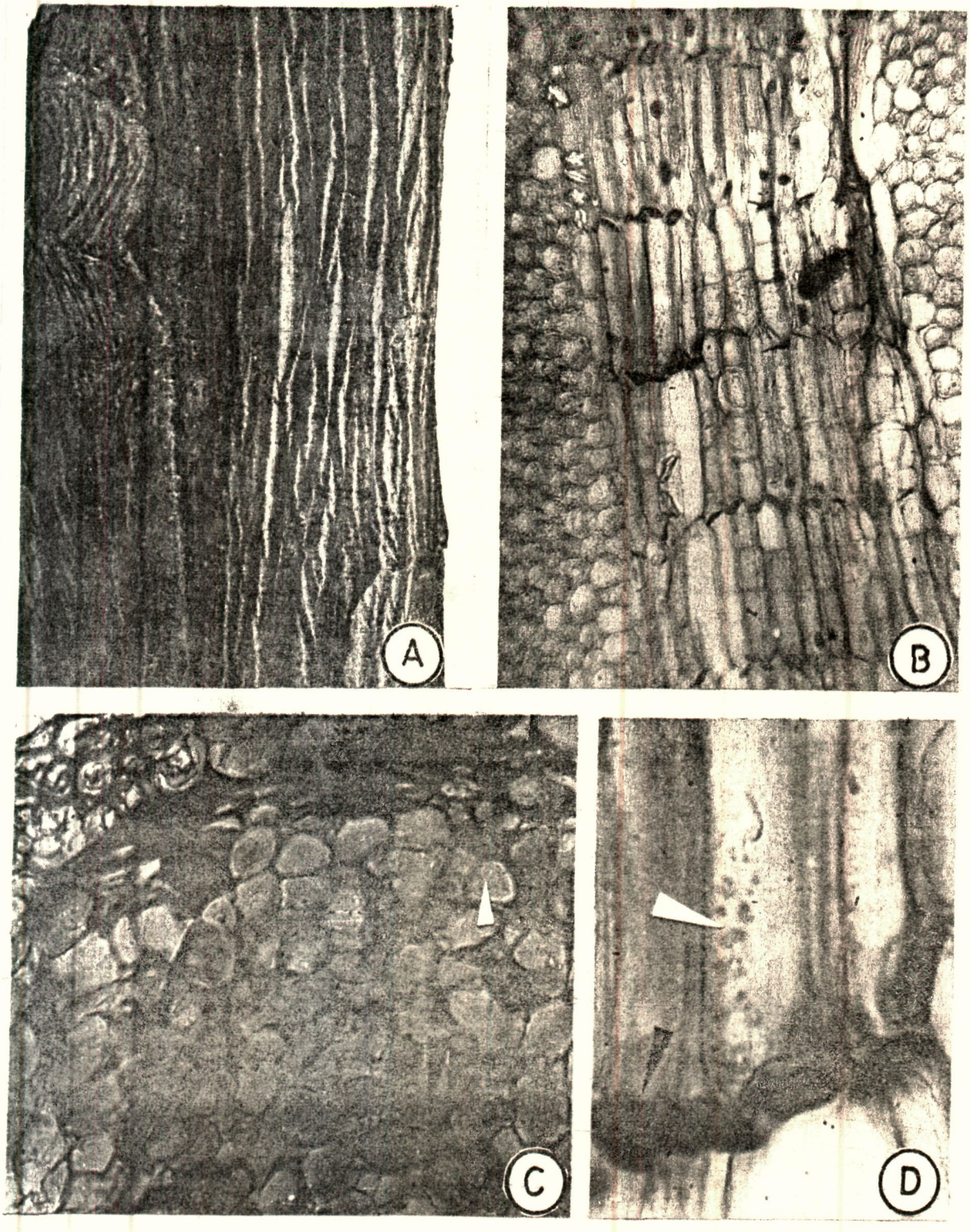

Plate - V.

A. Tree trunk of Erythrina suberosa showing fissuring of the bark.

B. Tangential longitudinal section of conducting phloem of E. suberosa showing sieve plate (black arrow) and lateral sieve areas (white arrow) (400X).

C. Tangential longitudinal section of conducting phloem of E. suberosa showing stratified sieve-tube elements (100X).

D. Transverse section of conducting phloem of E. suberosa showing sieve-tube elements (black arrow) and parenchyma (white arrow) (250X).

PLATE V

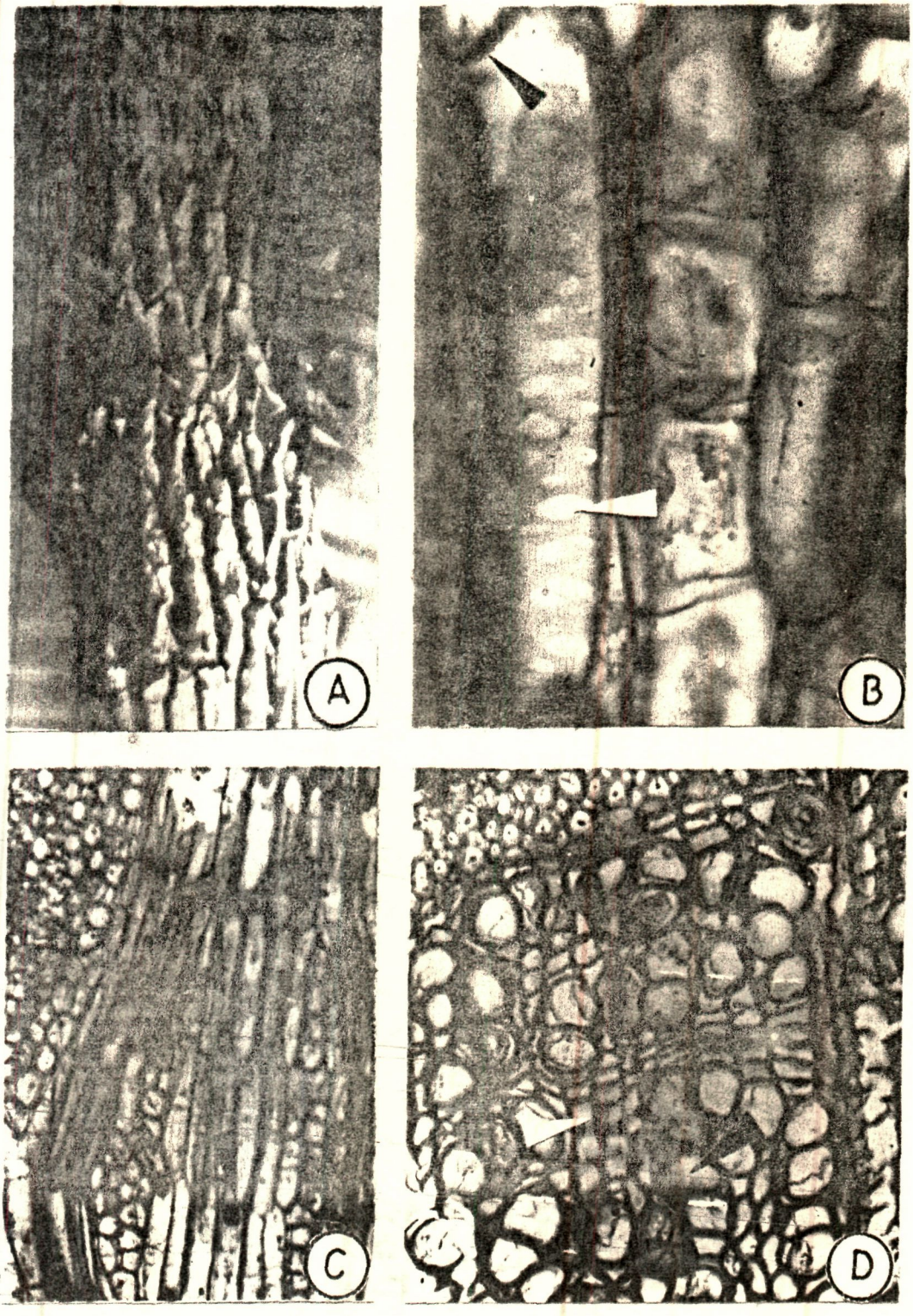

Plate - VI. A. Tree trunk of Gliricidia maculata showing fissuring of the bark.

B. Transverse section of conducting phloem of G. maculata showing sieve-tube elements (black arrow) and parenchyma (white arrow) (100X).

C. Tangential longitudinal section of conducting phloem zone of G. maculata showing sieve plate (black arrow) and lateral sieve areas (white arrow) (400X).

D. Tangential longitudinal section of conducting phloem of G. maculata showing stratified arrangement of sieve-tube elements and rays (250X).

PLATE VI

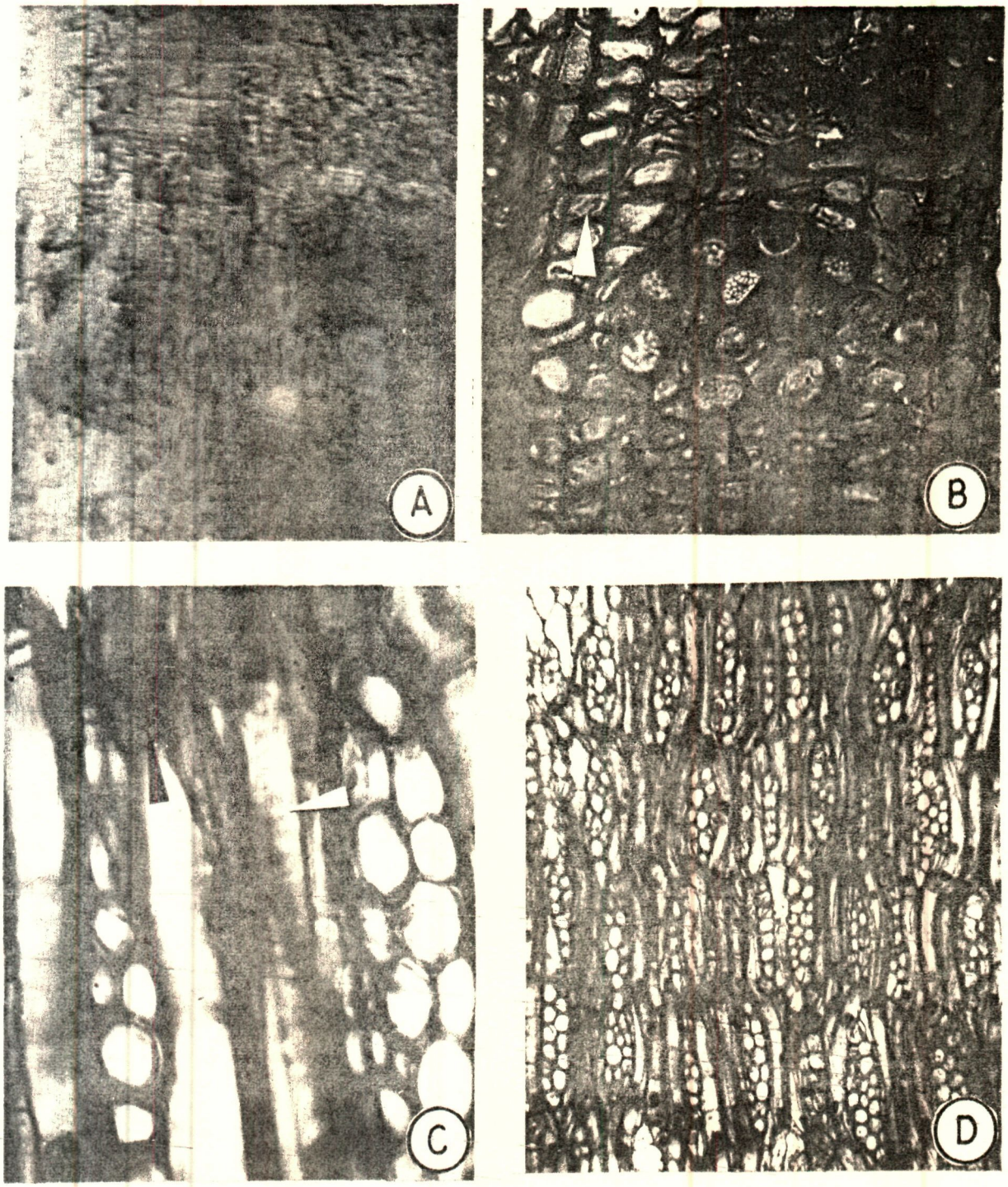

Plate - VII. A. Tree trunk of *Hardwickia binata* showing fissuring of the bark.

B. Tangential longitudinal section of conducting phloem zone of *H. binata* showing sieve plate (black arrow) and lateral sieve areas (white arrow) (400X).

C. Tree trunk of *Delonix regia* showing fissuring of the bark.

D. Transection of conducting phloem part of *H. binata* showing sieve-tube elements (black arrow) and parenchyma (white arrow) (250X).

PLATE VII

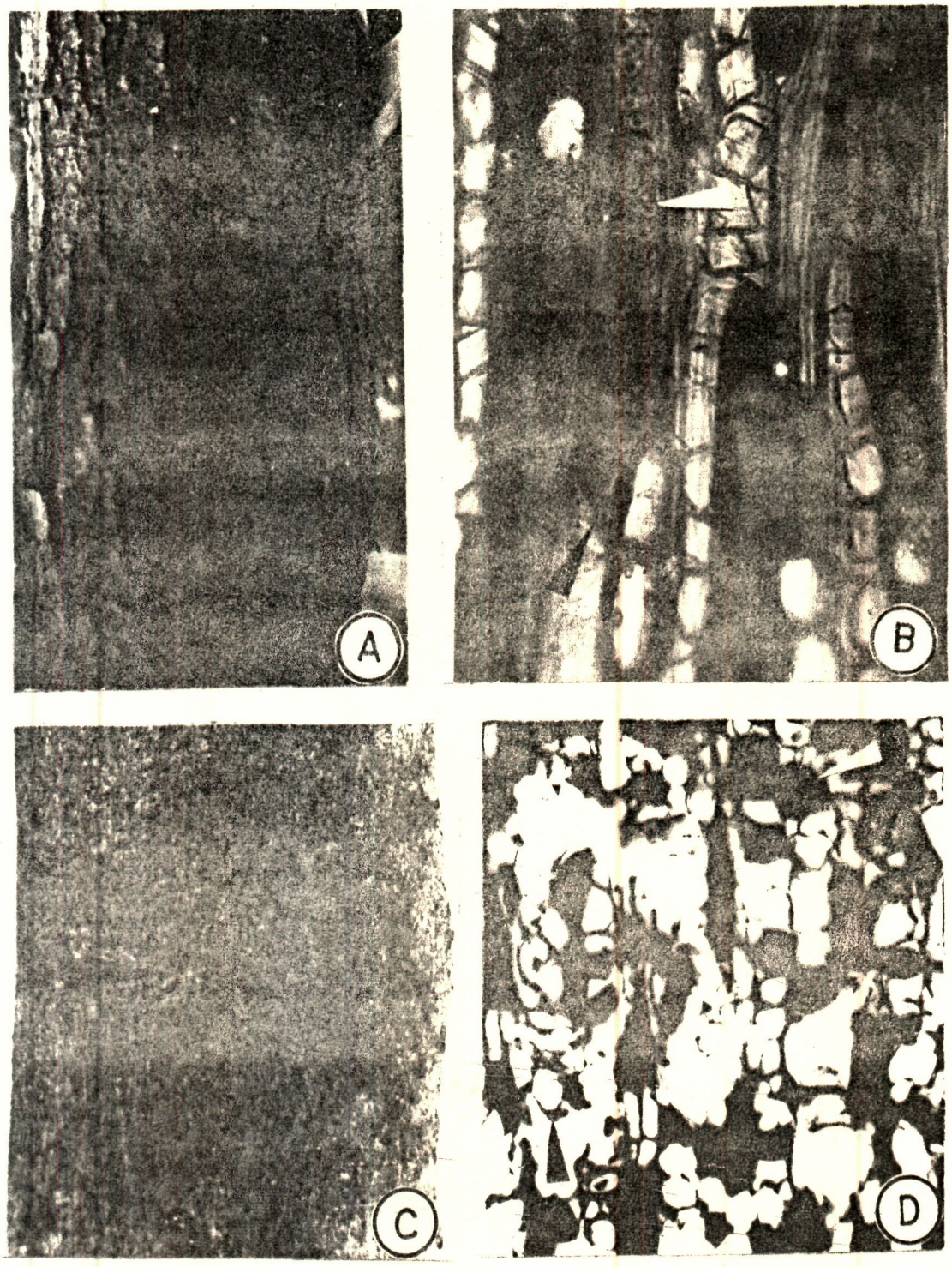

Plate - VIII. A. Tree trunk of *Parkia roxburghii* showing fissuring of the bark.

B. Transverse section of conducting phloem of *P. roxburghii* showing sieve-tube elements (black arrow) and parenchyma (white arrow) (250X).

C. Tangential longitudinal section of conducting phloem of *Delonix regia* showing sieve plate (black arrow) and lateral sieve areas (white arrow) (100X).

D. Transverse section of conducting phloem of *D. regia* showing gum duct (GD) and sieve-tube elements (black arrow) and parenchyma (white arrow) (100X).

E. Tangential longitudinal section of conducting phloem of *P. roxburghii* showing sieve plate (black arrow) and lateral sieve areas (white arrow) (400X).

PLATE VIII

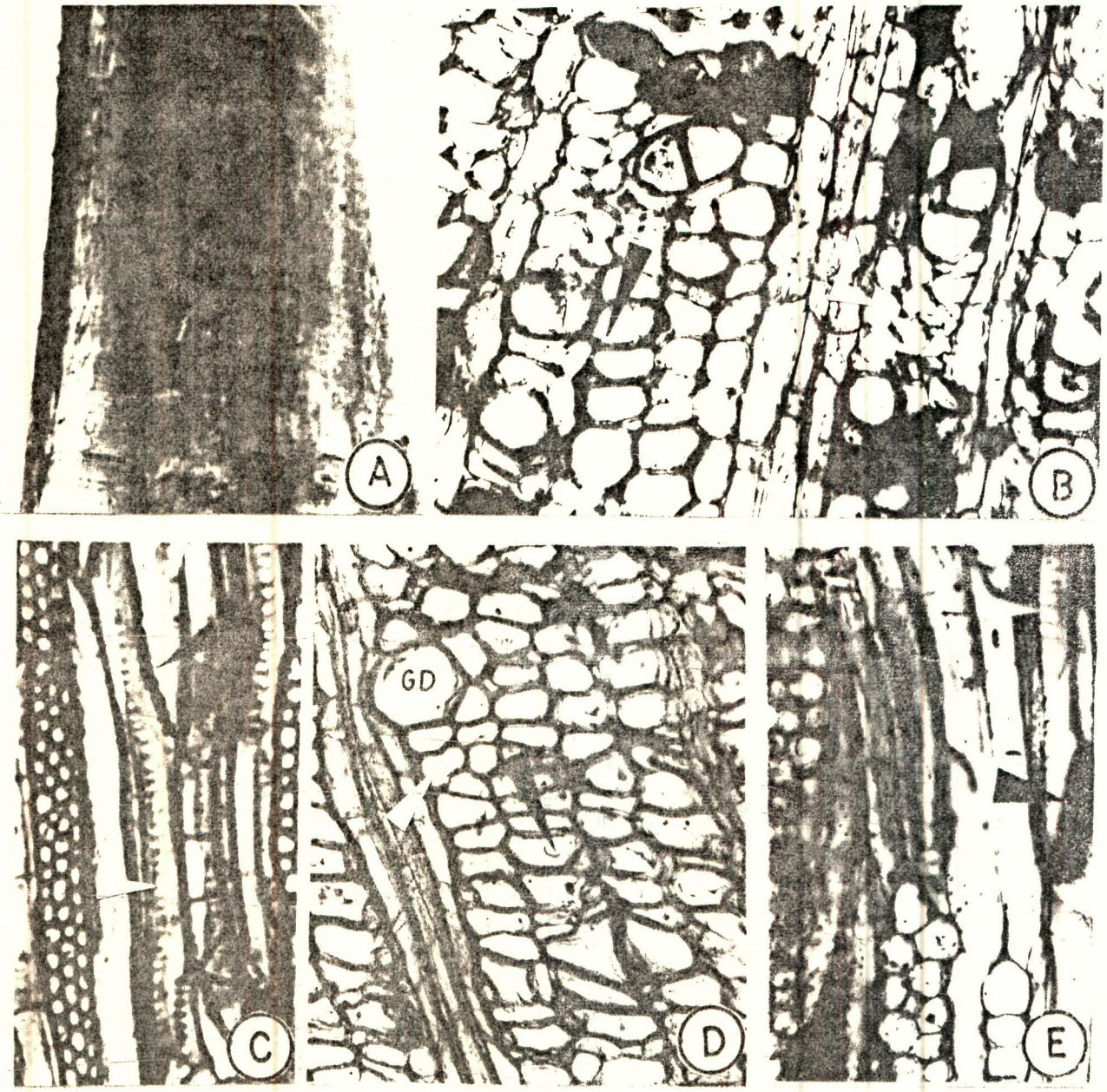

Plate - IX.

A. Tree trunk of Peltophorum pterocarpum showing fissuring of the bark.

B. Tangential longitudinal section of conducting phloem zone of P. pterocarpum showing sieve plate (black arrow) and lateral sieve areas (white arrow) (250X).

C. Tree trunk of Prosopis juliflora showing fissuring of the bark.

D. Transverse section of conducting phloem of P. pterocarpum showing sieve-tube elements (black arrow) and parenchyma (white arrow) (250X).

E. Tangential longitudinal section of P.juliflora showing sieve plate (black arrow) and lateral sieve areas (white arrow) (400X).

F. Transverse section of P. juliflora showing sieve-tube elements (black arrow) and parenchyma (white arrow) (250X).

PLATE IX

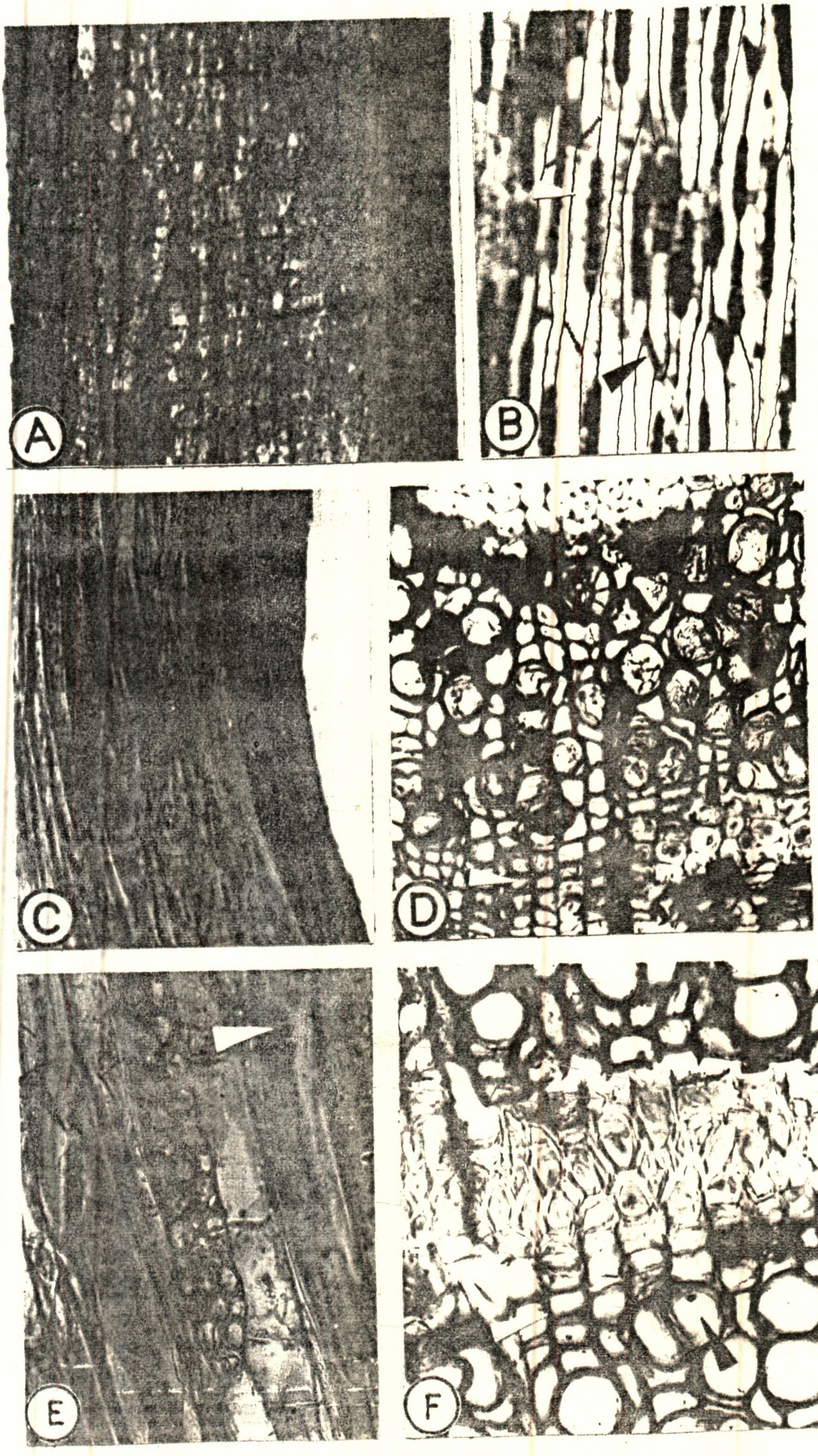

Plate - X. A. Tree trunk of Pterocarpus marsupium showing fissuring of the bark.

B. Transverse section of conducting phloem of P. marsupium showing gum duct (GD) (100X).

C. Tangential longitudinal section of conducting phloem of part of P. marsupium showing stratified arrangement of sieve-tube elements and rays (100X).

D. Tangential longitudinal section of conducting phloem of P. marsupium showing sieve plate (black arrow) and lateral sieve areas (white arrow) (400X).

E. Transverse section of conducting phloem zone of P. marsupium showing sieve-tube elements (black arrow) and parenchyma (white arrow) (100X).

PLATE X

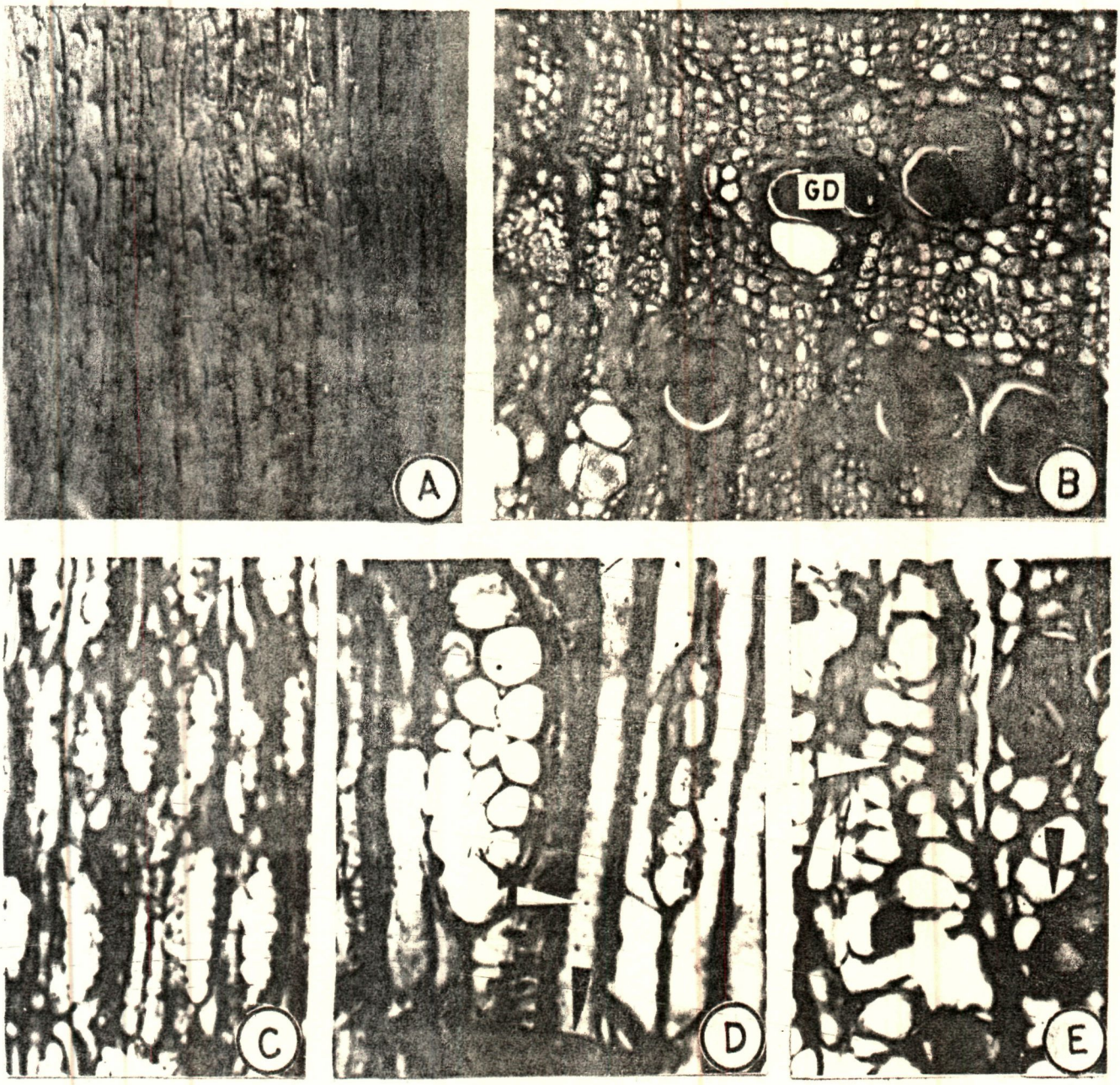

Plate - XI. A. Tree trunk of *Saraca indica* showing fissuring of the bark.

B. Tangential longitudinal section of conducting phloem of *S. indica* showing sieve plate (black arrow) and lateral sieve areas (white arrow) (400X).

C. Transverse section of conducting phloem of *S. indica* showing sieve-tube elements (black arrow) and parenchyma (white arrow) (250X).

D. Tree trunk of *Samanea saman* showing fissuring of the bark.

PLATE XI

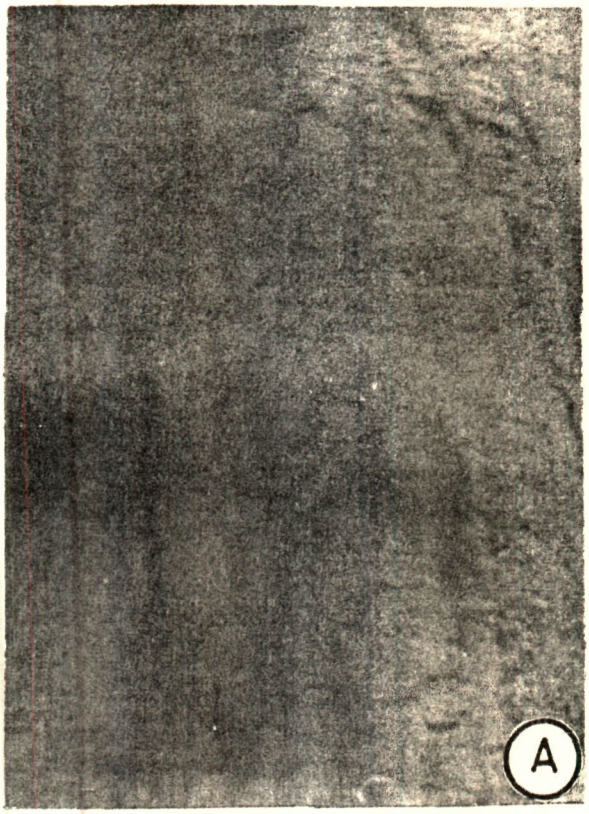

Plate - XII. A. Tangential longitudinal section of conducting phloem part of Samanea saman showing sieve plate (black arrow) and lateral sieve areas (white arrow) (400X).

B. Transverse section of conducting phloem of S. saman showing sieve-tube elements (black arrow) and parenchyma (white arrow) (250X).

C. Tree trunk of Sesbania grandiflora showing fissuring of the bark.

D. Tangential longitudinal section of conducting phloem of S. grandiflora showing stratified arrangements of sieve-tube elements and rays. (100X).

PLATE XII

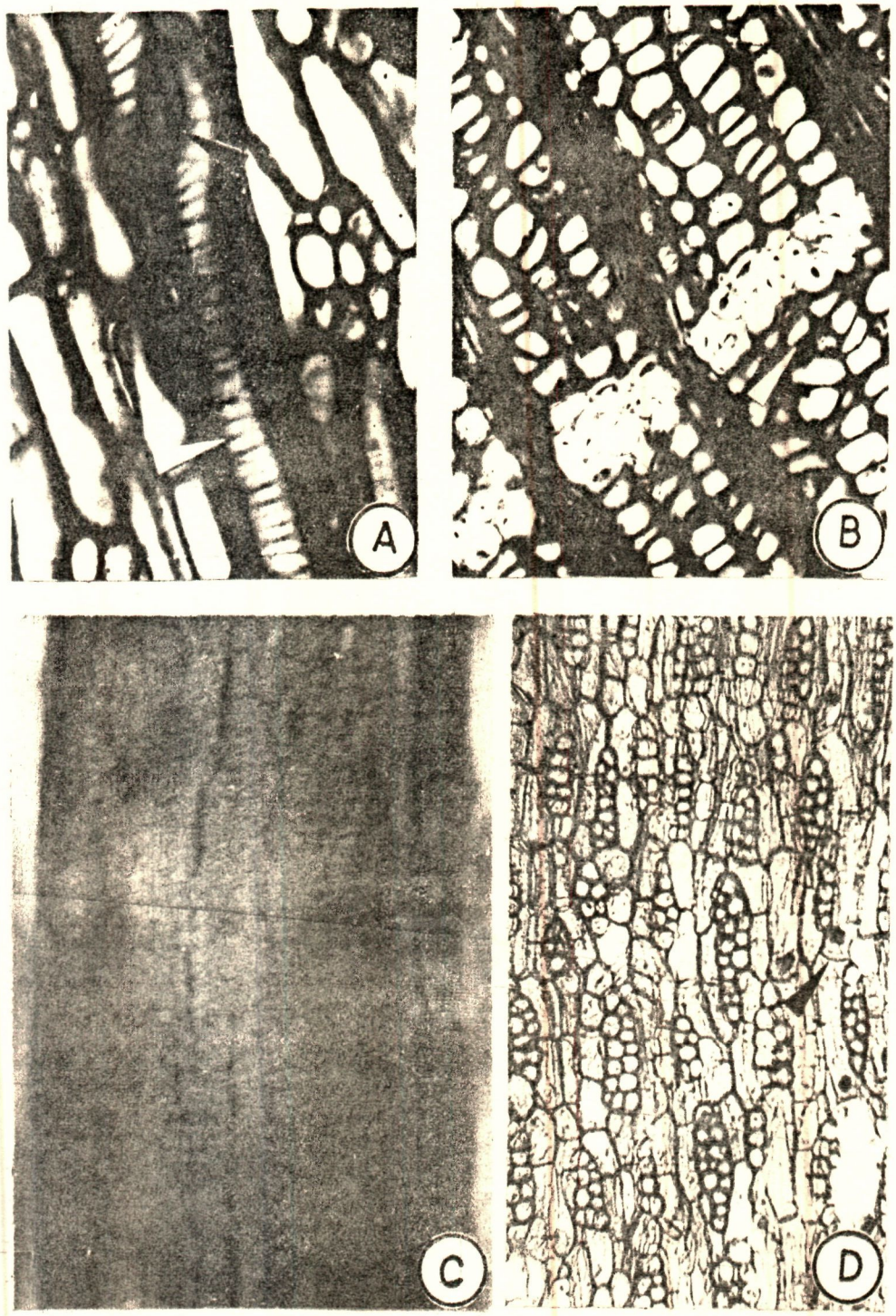

Plate - XIII. A. Tree trunk of *Tamarindus indica* showing fissuring of the bark.

B. Tangential longitudinal section of conducting phloem of *T. indica* showing sieve plate (black arrow) and lateral sieve areas (white arrow) (400X).

C. Transverse section of conducting phloem part of *Sesbania grandiflora* showing sieve-tube elements (black arrow) and parenchyma (white arrow) (250X).

D. Transverse section of conducting phloem of *T. indica* showing sieve-tube elements (black arrow) and parenchyma (white arrow) (250X).

PLATE XIII